National Park Service
U.S. Department of the Interior
National Historic Landmarks Program

American Aviation Heritage

Identifying and Evaluating Nationally Significant Properties in U.S. Aviation History

A National Historic Landmarks Theme Study

INFORMATION GPO

Cover: A Boeing B-17 "Flying Fortress" Bomber flies over Wright Field in Dayton, Ohio, in the late 1930s. Photograph courtesy of 88th Air Base Wing History Office, Wright-Patterson Air Force Base.

AMERICAN AVIATION HERITAGE

Identifying and Evaluating Nationally Significant Properties in U.S. Aviation History

A National Historic Landmarks Theme Study

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FOREWORD

From the Wright brothers to the present-day pioneers, no national community has contributed more to aerodynamics and to resulting flight technology than the United States.

–James Hansen[1]

On December 17, 2003, thousands gathered at the Wright Brothers National Memorial near Kitty Hawk, North Carolina, to witness the reenactment of a milestone in American aviation heritage. On that day, pilots in a reproduction wood-and-muslin 1903 Wright Flyer biplane taxied down a sloped ramp to re-enact the world's first powered flight by the Wright brothers 100 years earlier, a flight that would spawn the Air Age and change the world. One can see the original Wright Flyer, an icon of flight, within arm's length at the Smithsonian Institution's National Air and Space Museum. "Through the original artifact it is possible, to a degree," writes early aviation curator Peter L. Jakab, "to transcend time and identify with the Wright achievement in a very direct way. . . . The Flyer is a visible, tangible symbol of the monumental inventive effort that has immortalized the Wright name."[2]

In recognition of this heritage, the National Park Service and the U.S. Air Force funded this theme study to identify other tangible symbols that exemplify the past century's aeronautical achievements. As aerospace historian John Hansen states, "The inextricable link between the technical development of flight and the military's participation in that quest has been a persistent theme throughout the twentieth century."[3] To this end, the U.S. Air Force provides the introduction to this study and describes the important contribution Dayton, Ohio, has played in the history of aviation. From Huffman Prairie Flying Field where the Wright brothers flew, to Wright Field—a world class center of aviation technology and education, and today part of Wright-Patterson Air Force Base—Dayton has become synonymous with flight.

This study has two primary components. A national historic context judges the relative significance of people, places, and events that may be nationally significant in aviation history. The chapters provide a chronological approach to aviation history covering aviation's pioneering years, civil aviation, military aviation, and aeronautical technology. Serving as the foundation, and at times the narrative for the historic context, is a comprehensive library of essays completed by the U.S. Centennial of Flight Commission which was established by Congress in November 1998 through the "Centennial of Flight Commemoration Act" (Public Law 105-389). Aviation-related areas are not covered in the context include World War II in the Pacific, man in space, and rocketry. The first two topics are covered in separate theme studies and rocketry is considered a separate topic from the manned aviation flight covered in this essay.

The study's second primary component, the property section, assesses properties according to the NHL criteria and exceptions, and discusses the high degree of integrity required for National Historic Landmarks as described in the National Register Bulletin *How to Prepare National Historic Landmark Nominations*. Identified properties fall within three categories: those already

[1] James R. Hansen, ed., with D. Brian Taylor, Jeremy Kinney, and J. Lawrence Lee, *The Wind and Beyond: A Documentary Journey Into the History of Aerodynamics in America* (Washington, DC: National Aeronautics and Space Administration, NASA History Office, Office of External Relations, 2003), vol. 1, xxv.
[2] Peter L. Jakab, *Visions of a Flying Machine: The Wright Brothers and the Process of Invention* (Washington, DC: Smithsonian Institution Press, 1990), xiii.
[3] Hansen, *Wind and Beyond*, xlvi.

recognized as nationally significant, those recommended for further study, and those removed from further study.

Although a subject as vast as aviation history cannot be thoroughly exhausted in one theme study, this study provides the framework for identifying and evaluating many of the most remarkable achievements associated with this topic. As Tom D. Crouch, curator of Aeronautics of the Smithsonian's National Air and Space Museum states, "[T]he identification, preservation, and interpretation of historic sites, documents, and objects relating to the history of flight should be of concern to all of us who seek to better understand the foundations of the world in which we live."[4]

[4] Tom D. Crouch, "Flight in America, 1784-1919," *Cultural Resource Management*, no. 2 (2000): 8.

INTRODUCTION

Few technological advances have transformed America and its national character as much as the development of powered flight. Two brothers began their experimentation in a bicycle shop in Dayton, Ohio. They first demonstrated that manned, powered flight was possible at Kitty Hawk, North Carolina, in 1903, and refined their machine to a fully controllable, practical airplane back in Dayton at Huffman Prairie Flying Field in 1904 and 1905. That 1905 practical airplane laid the foundation for what is now a worldwide aviation industry that includes assets from national governments, military organizations, commercial, general, and private aeronautical enterprises. That early Wright Flyer, within a century, evolved into a wide variety of aircraft that today can fly—manned and unmanned—virtually anywhere on earth, and far beyond.

As aerospace historian Dr. Richard Hallion has argued, to appreciate the significance of powered flight, it may be sufficient to note the speed at which humans have been able to regularly transport themselves and their goods over the course of time. From the dawn of civilization until the 1830s, the speed of land transport over any significant distance was the speed of a horse-drawn wagon, or about six miles per hour. Water transport was only slightly faster. Over the next 70 years, the introduction of the railroad and advances in its technology increased the speed of practical human transport by about tenfold, to approximately 60 miles per hour. While the introduction of mass-produced automobiles reshaped the American landscape and society on an enormous scale, the automobile has not, in the course of a century, bested the railroad in the practical speed of transportation. By contrast, manned, powered flight—the technology made practical by Wilbur and Orville Wright and one roughly contemporaneous with the automobile—produced another quantum leap in the speed of human transport. In about the same span of years that the railroad required to take the speed of practical human transport from six miles per hour to sixty, the airplane multiplied it tenfold again, to about 600 miles per hour, the speed of a commercial jet transport. Aviation technologies likewise paved the way to space flight and space exploration.

At this scale, changes become qualitative as well as merely quantitative, and the airplane has transformed America in the twentieth century just as thoroughly as the railroad did in the nineteenth, opening a wide range of new possibilities. Aviation changed the way that Americans viewed the world, both figuratively and literally. Americans have become accustomed to seeing their world from above, either in aerial photographs or in imagery from satellites and manned spacecraft. The practical consequences of this change in perspective are amply illustrated just by the accurate prediction and tracking of hurricanes and tropical storms, which save countless lives each year. The completion of the first transcontinental railroad in 1869 cut travel time from the east coast of the United States to the west coast from months to about a week. The commercial airliner reduced it to a matter of hours, further making the world "smaller," and, through air freight operations, bringing producers and consumers closer together. And, as aviation changed the way America conducted its business in peacetime, it likewise transformed the practice of war, accounting in large measure for the emergence of the United States as the premier military power on Earth in the course of a single century.

The city of Dayton, Ohio, and its surrounding region serve as a microcosm of the development of American aviation. Dayton is home to the bicycle shop where Wilbur and Orville Wright first

dreamed of powered flight and to the field where they perfected the world's first practical airplane and had the first permanent flight school. Beyond that, it is the location of sites such as Wright Field where, from 1927 to 1945, the U.S. Army Air Corps and the U. S. Army Air Forces—the precursors to today's United States Air Force—vaulted to a position of preeminence in air power. Virtually everything that went into making that Air Force was substantially shaped by, and passed through, Wright Field. Within those decades the name "Wright Field" became synonymous with the development of American military aviation. Technologies researched, developed, tested and acquired by Wright Field personnel included air-cooled radial engines, superchargers and turbosuperchargers, controllable-pitch and full-feathering propellers, high-octane fuels, pressurized cabins, blind-flying instrumentation, free-fall parachutes, helicopters, autogiros, gliders and virtually every Army aircraft type used in World War II. Initial modifications to a B-29 aircraft used in the test program for the Manhattan Project were performed at Wright Field.

From 1927 through 1939, Wright Field served as a world class center of aviation technology and education. The work performed there transformed the nation's air forces from a fleet of open cockpit, canvas-winged biplanes to an armada of high-altitude, single-wing, multi-engine war machines. The Field's School of Engineering professionalized aeronautical engineering, technology, logistics, and military aviation and sent forth a corps of highly trained officers to carry on the work. The 1940-1945 Army Air Forces era found Wright Field immersed in equipping the air forces for World War II. Research and development progressed quickly as Wright Field became the bustling center for the aviation component of the war effort. Its research, test, logistics, and administrative facilities underwent quick and dramatic expansion to meet the demands of a global war. The Field's scientists, engineers, and technicians rapidly advanced the development and expansion of the nation's military aviation program. Their cutting edge discoveries and inventions built the fleet that conquered the air, enabling the defeat of the Axis powers. The concepts and technical innovations explored and taught at Wright Field established the foundation, direction, energy, and ingenuity that became the U. S. Air Force. Numerous buildings and other facilities dating from the interwar and World War II eras remain in use today.

Adjacent to Wright Field, and part of it from 1927-1931, stood Patterson Field. Encompassing the site of the Wright brothers' experiments and flying school, Patterson's heritage of military aviation began in 1917 with the establishment of Wilbur Wright Field and the Fairfield Air Depot. These installations served to train military aviators, mechanics, and armorers and to perform flight testing and logistical functions during World War I and beyond. In 1924, the site hosted the International Air Races sponsored by the National Aeronautic Association, one of many activities aimed at promoting "air-mindedness" in the American public. In 1934, Patterson Field prepared the aircraft for the historic 8,290-mile "Alaska Flight" and supported this major demonstration of air power. The Field was the site of the world's first entirely automatic landing in 1937.

Together, Wright Field and Patterson Field have significant associations with major figures in the history of American aviation. General Henry H. Arnold, commander of the United States Army Air Forces during World War II, and the only "five-star" general in the history of the Air Force, learned to fly at Huffman Prairie Flying Field, instructed by the Wright brothers. As a

major, Arnold commanded the Fairfield Air Depot (later part of Patterson Field) from 1929 to 1931, before going on to lead the 1934 "Alaska Flight." Other aviators trained to fly at Huffman Prairie Flying Field included Canadian ace A. Roy Brown, credited with the aerial victory that ended the career of the "Red Baron," Manfred von Richtohofen. James H. ("Jimmy") Doolittle, known primarily for his leadership of the "Doolittle Raid" against Japan in 1942, served as a test pilot at Wright Field's predecessor installation, McCook Field, in Dayton. Likewise, Brigadier General Charles E. ("Chuck") Yeager, the first pilot to break the sound barrier, first served as a test pilot at Wright Field. Wright-Patterson Air Force Base, which combined Wright and Patterson Fields into a single institution in 1948, also houses facilities significant to the history of the Cold War, including facilities directly related to the development of stealth technology.

The Dayton region is also home to the Neil Armstrong Air & Space Museum, the WACO Museum and airfield, which chronicles WACO's dominance of civilian general aviation aircraft production between the two world wars, and to sites related to a little-known but critical aspect of the Manhattan Project. There are other significant civil aviation sites in the Dayton region, and several national aviation sites, including the National Museum of the United States Air Force, Dayton Aviation Heritage National Historical Park, and the National Aviation Hall of Fame. The rich aviation heritage of the region led Congress to designate an eight-county portion of southwest Ohio as the National Aviation Heritage Area in 2004.

However, on a national scale, many of the sites associated with the story of American aviation are not protected for future generations. With the advent of the 100th anniversary of powered flight in 2003, members of Congress and the aviation community proposed that the National Park Service prepare a National Historic Landmark Theme Study on the history of American aviation, to ensure that there is increased knowledge about this great American story, and that from this knowledge the American people can determine how to best preserve and protect this important part of our nation's heritage.

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PART ONE – THE PIONEERING YEARS, 1861-1909

Wright brothers glider at Kitty Hawk, North Carolina, 1911. Source: Library of Congress, Prints and Photographs Division [LC-DIG-ppprs-00693]

1. BALLOONING IN THE CIVIL WAR[1]

In 1783, two Frenchmen, Jean-François Pilâtre de Rozier and François Laurent le Vieux d'Arlandes, made the first manned flight in an untethered balloon. Their flight sparked widespread interest across Europe and, in following years, flights were staged across the continent. Although Benjamin Franklin, Thomas Jefferson and others informed the American public about these aeronautical advances in Europe, ballooning was slow to develop in the United States. Ten years after the first ascent in Europe, Frenchman François Blanchard made the first untethered balloon flight in the United States. Ascending from the yard of the Washington Prison in Philadelphia, Pennsylvania, on January 9, 1793, Blanchard carried the first piece of airmail, a "passport" presented by President George Washington, directing all U.S. citizens to "establish and advance an art [ballooning], in order to make it useful to mankind in general."[2]

Blanchard's feat was emulated by countless others and within twenty-five years of his ascent, the first generation of American aeronauts had begun to attract thousands of spectators. Madame Johnson, a little-known figure whose background is elusive, was the first woman to fly in the United States. Her first ascent was made at New York's Castle Garden [NR, 1966] on October 24, 1825. By 1828, most of Johnson's ascents were from Niblo's Garden in Manhattan, New York. Like Johnson, Charles Ferson Durant, the most significant and inspiring of the first generation of American aeronauts, made his first ascent from Castle Garden, some five years later on September 9, 1830. Following Durant's flight, ballooning became a regular form of entertainment at fairs and celebrations throughout the 1850s as itinerant balloonists, novices, and experts, traveled the nation from Maine to California, thrilling audiences. Honored as "Professor This" or "Madame That," these footloose aerial showmen were a breed apart.[3] By 1860, ballooning's first heyday in America was drawing to a close.[4]

Balloon Reconnaissance in the Civil War

With the advent of the Civil War, the focus of American ballooning shifted. Several factors led to the introduction of military ballooning in the United States. As "[t]he struggle was so titanic and the stakes so high—nothing less than survival as a nation—…both the federal government and the rebellious Confederate States of America eagerly accepted any innovation that might provide an advantage in battle."[5]

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[1] Portions of this section were excerpted or paraphrased from U.S. Centennial of Flight Commission, "Balloons in the American Civil War," http://www.centennialofflight.gov/essay/Ligher_than_air/Civil_War_balloons/LTA5.htm (accessed February 17, 2004).

[2] Aviation historian Tom Crouch calls the Washington Prison the Walnut Street Prison. Tom D. Crouch, *The Eagle Aloft: Two Centuries of the Balloon in America* (Washington, DC: Smithsonian Institution Press, 1983), 106. For a full discussion of Blanchard's American tour, see Crouch, 103-17. William H. Longyard, *Who's Who in Aviation History: 500 Biographies* (Shrewsbury, UK: Airlife Publishing, 1994), 25-26.

[3] Crouch, *Eagle Aloft*, 201-02.

[4] Ibid., 157; F. Stansbury Haydon, *Military Ballooning During the Early Civil War* originally published as *Aeronautics in the Union and Confederate Armies, with a Survey of Military Aeronautics prior to 1861*, vol. 1 (Baltimore: John Hopkins Press, 1941; repr., Baltimore: John Hopkins University Press, 2000), 33, 38.

[5] Alfred F. Hurley and William C. Heimdahl, "The Roots of U.S. Military Aviation," in *Winged Shield, Winged Sword: A History of the United States Air Force*, vol. 1, ed. by Bernard C. Nalty (Washington, DC: Air Force History and Museums Program, 1977), 3-4.

The most experienced balloonists, including Northerners Thaddeus Lowe and John La Mountain, remained loyal to the United States.[6] Both Lowe and La Mountain became closely associated with the federal government's ballooning program. Lowe's association began when one of his financial supporters, Murat Halstead, editor of the *Cincinnati Daily Commercial,* wrote to Secretary of the Treasury Salmon P. Chase, suggesting that the United States establish a balloon corps. Secretary Chase arranged a meeting between Lowe and President Abraham Lincoln and, on June 18, 1861, with the aid of the secretary of the Smithsonian, Lowe demonstrated both balloon reconnaissance and the transmittal of telegrams from the balloon to the commanders below. Using street gas from one of the gas mains at the Columbian Armory (currently the site of the Smithsonian National Air and Space Museum), Lowe made tethered ascensions in the *Enterprise* from the armory, the grounds of the Smithsonian, and the South Lawn of the White House. On that day he also made the first airborne telegraphic communication:[7]

> Balloon Enterprise, June 1[8], 1861
> To the President of the United States:
> Sir;
> This point of observation commands an area nearly 50 miles in diameter. The city, with its girdles of encampments, presents a superb scene. I have pleasure in sending you this first dispatch ever telegraphed from an aerial station, and in acknowledging indebtedness for your encouragement for the opportunity of demonstrating the availability of the science of aeronautics in the military service of the country.[8]

Lowe's demonstrations convinced Lincoln of the merits of this new technology. Later that summer, Lincoln established the Balloon Corps, a civilian organization under the authority of the Union's Bureau of Topographical Engineers, and granted Lowe, its commander, permission to requisition equipment and personnel.[9] Lowe received funds to build a balloon on August 2, 1861, and chose Fort Corcoran as his base of operations.[10] The first U.S. balloon designed for military use, the *Union*, was ready for action on August 28. Because Lowe had to inflate the balloon with gas from municipal lines in Washington, D.C. (he had not yet received funds for a portable gas generator), the balloon could not move far. Lowe made daily ascensions and reported his observations to his commanding officers. He became increasingly adept at assessing whether clouds of dust were made by troops, horses, or wagons. He could even extrapolate the number of men marching.[11] On September 24, 1861, Lowe ascended more than 1,000 feet near Arlington, Virginia, across the Potomac River from Washington, D.C. There, he began telegraphing intelligence on Confederate troops located at Falls Church, Virginia, more than three miles away. Aerial reconnaissance of the enemy's position allowed Union guns to fire accurately at the Confederate troops—a first in the history of warfare.

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[6] Ibid., 4.
[7] Davis S. Heidler and Jeanne T. Heidler, eds., "Balloons," in *Encyclopedia of the American Civil War: A Political, Social, and Military History,* vol.1 (Santa Barbara: ABC-CLIO, 2000), 164.
[8] Quoted in Crouch, *Eagle Aloft,* 346, from United States War Department, *The War of Rebellion: A Compilation of the Official Records of the Union and Confederate Armies*, vol. 3 (Washington, DC: Government Printing Office, 1899), 254.
[9] Heidler and Heidler, "Balloons," 164; Crouch, *Eagle Aloft,* 345-46.
[10] Fort Corcoran stood in what is present day Arlington, Virginia. During the time of the American Civil War the area was known as Alexandria County. Arlington Historical Society, "Military-Use Structures," http://www.arlingtonhistoricalsociety.org/learn/sites_properties/military_use.asp (accessed October 25, 2004).
[11] Jake Brouwer, "Observations from Above," http://www.aaaim.com/echo/v3n2/v3n2ObservationsFromAbove.htm (accessed October 27, 2004).

Secretary of War Simon Cameron then directed Lowe to build four additional observation balloons, and soon thereafter another two small balloons. The fleet now consisted of the *Union*, *Intrepid*, *Constitution*, *United States*, *Washington*, *Eagle*, *Excelsior*, and Lowe's *Enterprise*. These balloons ranged from 15,000 to 32,000 cubic feet in capacity, and each had enough cable to climb 5,000 feet.[12]

Lowe's fellow aeronaut, John La Mountain, also offered the Union Army his balloon services in 1861. Although La Mountain, who lacked influential backers, never received a response, Maj. Gen. Benjamin F. Butler, the commander of Union Forces at Fort Monroe [NHL, 1960] in Hampton, Virginia, asked for a demonstration. After La Mountain made several successful ascents at Fort Monroe between July 31 and August 10, 1861, in his balloon, the *Atlantic*, Butler hired him as an independent civilian aeronaut.

On October 15, 1861, La Mountain made his first experimental untethered flight reconnaissance over the Confederate line close to Camp Williams. He attempted a second free flight reconnaissance on October 18 from Cloud's Mill, Virginia. According to *The New York Times*, La Mountain could see the Confederate encampments beyond Newmarket Bridge, Virginia, and at the James River north of Newport News. Flying 1,400 feet above Confederate territory, Lowe viewed "troop concentrations at Fairfax Station, Manassas, and Centreville, saw gun batteries on Aquia Creek, and noted the movement of several trains."[13]

In addition to aerial reconnaissance and telegraphy, both Lowe and La Mountain introduced "aircraft carriers" for launching balloons. On August 3, 1861, La Mountain launched an observation balloon 2,000 feet over the James River from the deck of the *Fanny*, giving the small tugboat the distinction of being the first aircraft carrier. La Mountain's ascension "began the widespread use of balloons for reconnaissance work during the Civil War and foreshadowed the navy's future use of the air to extend its effective use of sea power."[14] That same year, Lowe directed the modification of a coal barge, the *George Washington Parke Custis*, "for launching a passenger-carrying aerial device."[15] The *Custis* was purchased by the navy in 1861 and retrofitted with gas-generating equipment developed by Lowe, with modifications made by John A. Dahlgren at the Washington Navy Yard [NHL, 1976]. In September, Lowe launched an observation balloon from the flight deck of the *Custis*, making it the first vessel modified for use as an aircraft carrier.[16] On November 10, 1861, the *Custis* was towed three miles along the Potomac from the headquarters of Gen. Joseph Hooker at Budd's Ferry, to the mouth of Mattawoman Creek at Stump Neck, Maryland. The following evening, Lowe and his assistants ascended in the *Constitution* and made an aerial reconnaissance of the southern side of the Potomac. "We had a fine view of the enemy camp fires during the evening," Lowe stated, "and saw rebels constructing batteries at Free Point."[17] Lowe's ascension at Stump Neck marks the first use of an "aircraft carrier" in American military history.[18]

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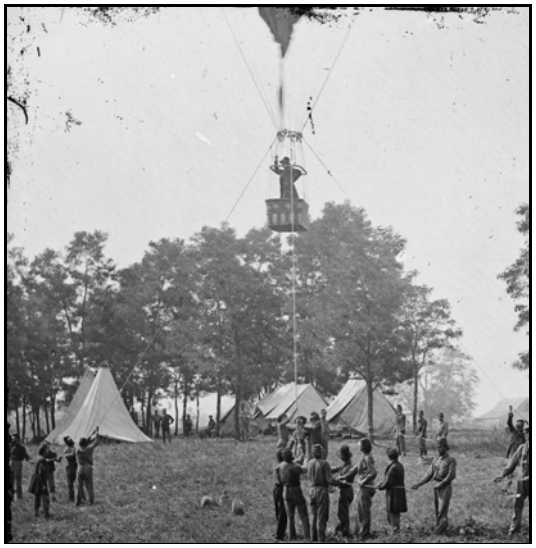
[12] Crouch, *Eagle Aloft*, 357, 358.
[13] Ibid., 364.
[14] La Mountain later used the Union tugboat, the *Adriatic*, as a balloon launch. U.S. Department of the Navy, Naval Historical Center, "*George Washington Parke Custis*," http://www.history.navy.mil/danfs/g4/george_washington_parke_custis.htm (accessed October 6, 2004).
[15] Edmund Preston, "From Balloons to Rockets: Maryland Aviation in Context," in *Maryland Aloft: A Celebration of Aviators, Airfields and Aerospace* (Crownsville: Maryland Historical Trust Press, 2003), 3.
[16] U.S. Department of the Navy, Naval Historical Center, *Dictionary of American Naval Fighting Ships*, vol. 3 (Washington, DC: Government Printing Office, 1968), 87.
[17] U.S. Department of the Navy, Naval Historical Center, "*George Washington Parke Custis*."
[18] Preston, "From Balloons to Rockets," 3.

Because La Mountain lacked the backing of the Union Army, he found it difficult to obtain equipment. Although he managed to obtain another balloon, the *Saratoga*, it was lost on November 16, 1861. When La Mountain attempted to acquire some of Lowe's equipment, Lowe refused to cooperate. As each man found his own supporters, the rivalry between the two escalated. General McClellan finally dismissed La Mountain from further service to the military on February 19, 1862. Nonetheless, La Mountain had conducted the first aerial reconnaissance of the Civil War and the first intelligence gathering by free balloon flight, a significant contribution to naval warfare and technology.



Thaddeus Lowe transmits observations on enemy troop positions at the Battle of Fair Oaks (Virginia) from the balloon the Intrepid. Source: Library of Congress, Prints and Photograph Division [LC-DIG-cwpb-01560]

Lowe continued to provide tactical reports to the Union troops. On May 31, 1862, during the Battle of Fair Oaks in Virginia, Lowe transmitted information on enemy troop positions that proved crucial to the Union victory. The presence of Union balloons forced the Confederates to conceal their forces by blacking out their camps after dark, creating dummy encampments and gun emplacements, and dispersing troops—all of which cost valuable time and personnel.[19] Lowe's reconnaissance activities also provided valuable information during the siege of Yorktown, Virginia. In late April 1863, he transmitted hourly reports on Confederate movements at Fredericksburg.

The Confederate Army also formed a smaller version of the Balloon Corps. In the spring of 1862, Capt. John Randolph Bryan offered to oversee the building and deployment of an observation balloon. Unlike the hydrogen-filled Union balloons, this observation balloon was a Montgolfière—filled with hot air—because the Confederacy did not have the equipment for generating hydrogen in the field. Bryan launched the balloon on April 13, 1862, over Yorktown. Although the balloon rotated on its single tether, Bryan managed to sketch a map of Union positions. His next ascent found Bryan in free flight after the tether was cut to untangle a ground crew member. Thinking he was the enemy, Confederate troops fired at the balloon but Bryan managed to escape and land safely.

A second Confederate balloon soon followed. Although rumored to have been made from silk dresses donated by the ladies of the Confederacy, this "silk dress balloon" was constructed from multicolored dress silk, not actual dresses. In the spring of 1862, Capt. Langdon Cheeves, known as the "father of the Confederate Air Force," assembled the balloon in Savannah's Chatham Armory. The balloon was filled with gas in Richmond, Virginia, tethered to a locomotive, and carried to the field. On July 4, 1862, when the battle area moved further from the railroad, the balloon was attached to a tugboat named the *Teaser* and carried down the James River where it ran aground and was captured.[20]

[19] Crouch, *Eagle Aloft*, 356.

[20] Ibid., 394. Another "silk dress balloon" was constructed and went into service at Richmond in the fall of 1862. It provided aerial observations from its post until the summer of 1863 when it escaped in a high wind and was

Despite early evidence of the value of military observation balloons, the Union Army's commanding generals probably did not use balloon observations advantageously. Vague reports of Robert E. Lee's movements issued from the hydrogen balloon *Intrepid* during the 1862 Peninsula Campaign apparently served only to panic General McClellan. Rather than attack the sparsely defended Confederate capital, McClellan withdrew his vastly superior forces and positioned them seven miles from Richmond, Virginia. His failure to act ensured the continuation of the war. After McClellan was relieved of his command on November 5, 1862, Maj. Gen. Ambrose Burnside took over and reorganized the Army of the Potomac. Following two years of service to the Army of the Potomac, factors such as political infighting, frequent changes in leadership, and lack of support from Washington ultimately led to the Balloon Corps' demise.[21]

captured by Union troops. U.S. Centennial of Flight Commission, "Balloons in the American Civil War."
[21] Crouch, *Eagle Aloft*, 411, 413; Heidler and Heidler, "Balloons," 167.

2. EARLY AVIATORS & FLYING MACHINES[1]

The Wright brothers are, undoubtedly, the most prominent pioneers of U.S. aviation history. After years of struggle, the brothers developed and flew the world's first airplane at Kitty Hawk in December 1903. According to the leading historian on the Wright brothers, Tom D. Crouch, "Wilbur and Orville Wright hold an almost unique position in the history of technology. It is impossible to overemphasize the magnitude of their achievement. Their own brilliant insight and inspired research strategy, perseverance and determination enabled them to move beyond their contemporaries with amazing rapidity."[2]

The Wright brothers' work followed that of Samuel Pierpoint Langley and Octave Chanute, two central figures in aviation experimentation and research. Langley's status as one of the nation's leading scientists and the third secretary of the Smithsonian Institution ensured that his attempts at flying in the late nineteenth and early twentieth centuries were taken seriously. Chanute, a civil engineer and the first aviation historian, produced the most significant aircraft of the pre-Wright era and served as a conduit for aviation advances between the Wrights and the fledgling aviation community. Together these men revolutionized the pioneering era of American aviation.

Samuel Pierpont Langley

Original Allegheny Observatory. Source: University of Pittsburgh, http://www.pitt.edu/~aobsvtry/history.html

Although his attempts at powered flight ultimately failed, Samuel Pierpont Langley's experiments explored important issues relating to flight and demonstrated the need to use a sound research methodology. Langley became professor of physics and director of the Allegheny Observatory at Western University of Pennsylvania (later the University of Pittsburgh) in 1867. At the observatory, he built "whirling tables" to demonstrate the ratio between power and lift. Langley's work began with two small-scale models. Because the first of these was destroyed in a windstorm, the second was built in the observatory's darkroom. Between the summer and fall of 1887, Langley moved to a full-scale model with a 60-foot diameter whirling arm. Based on the whirling tables, Langley concluded that "the faster a surface moved through the air, the lower were the power requirements necessary to maintain it at that speed," or simply stated, "the higher the speed, the lower the drag." Later evidence would disprove "Langley's Law."[3]

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[1] Much of this section on early aviators is based on the work of Tom D. Crouch, "the world's preeminent Wright brothers' scholar and author of the prize-winning *The Bishop's Boys*" as quoted in James R. Hansen, ed., *The Wind and Beyond: A Documentary Journey into the History of Aerodynamics in America*, vol. 1, *The Ascent of the Airplane*, NASA History Series (Washington, DC: NASA, 2003) 23, n. 25.

[2] Tom D. Crouch, *A Dream of Wings: Americans and the Airplane, 1875-1905* (Washington, DC: Smithsonian Institution Press, 1989), 224.

[3] Judy Rumerman, "Efforts at Powered Flight During the Last Decade Before the Wright Brothers," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Prehistory/Last_Decade/PH5.htm (accessed October 8, 2004); Crouch, *Dream of Wings*, 48-50, 54-55; Hansen, *Wind and Beyond*, 89; quotes, Crouch, 54, and Hansen, 89.

In 1887, Langley became assistant secretary of the Smithsonian Institution in Washington, D.C. He now turned his efforts to developing an airplane, directing aerodynamic work at both the observatory and the Smithsonian. At the Smithsonian, Langley obtained valuable research support not readily available to him during his years at the observatory. Between 1887 and 1903, the carpentry and machine shops in the Smithsonian South Shed became a research and development facility for the creation of a flying machine. Langley's experiments in wind studies at both the Smithsonian and the observatory fueled his enthusiasm for flight. However, as Tom Crouch states, "[b]oth experiments in aerodynamics and the wind studies were preliminaries that had little effect on Langley's conception of the successful flying machine."[4]

Langley's Aerodromes

In 1887, Langley designed dozens of rubber-band-powered models that were built by colleagues at the observatory, and later by Smithsonian staff. Learning little from the rubber-powered models, Langley decided to build larger steam-powered models he called aerodromes. Beginning in 1891, he began experimenting with many combinations of wings, fuselages, propellers, and tail assemblies using the large whirling arm at the Smithsonian. Crouch describes this shift as a major turning point in Langley's aeronautical career whereby he was "treading new ground."[5] Langley's research results and conclusions were published by the Smithsonian Institution in *Experiments in Aerodynamics*; they were the "first substantive American contribution to aerodynamics."[6]

In 1892, Langley built a larger aerodrome featuring tandem 14-foot-wide wings and a lightweight steam engine. To test his aerodromes, Langley decided to catapult them over a large body of water. He tested potential launchers at the Washington National Zoo and selected a catapult featuring "a long arm with a track on which the aerodrome would sit." In November 1892, Langley purchased a 12-by-32-foot houseboat and built a shack on the deck, 16 feet above water level, to launch the aerodrome. Two rooms on the houseboat served as "light shop facilities" for aircraft assembly, storage, and repair. For a launch site, Langley chose Chopawamsic Island, about 30 miles south of Washington near Quantico, Virginia. Here the majority of the river was shallow enough to retrieve the aerodrome following the flight.[7] In 1893, he used the houseboat to launch his latest aerodrome. But the aerodromes were too delicate and lacked the power to sustain themselves.

Langley's first success came on May 6, 1896, when a catapult launched *Langley Aerodrome No. 5* from the houseboat. On that afternoon, *No. 5* flew in a curved course for about 3,300 feet and flew a second time for about 2,300 feet. Telephone inventor and Langley supporter Alexander Graham Bell witnessed the flights. Describing the second trial, Bell wrote, "It ascended again in the face of the wind, afterwards moving steadily and continually in large curves accompanied with a rising motion and a lateral advance. Its motion was, in fact, so steady, that I think a glass of water on its surface would have remained unspilled."[8] That day Bell encouraged Langley to

[4] Crouch, *Dream of Wings*, 53, 56, 59; quote, 129.
[5] Ibid., 57, 59. Langley called the craft "aerodromes" based on the Greek word *aerodromoi* meaning "air runners." He had created a word, however, meaning a place where aircraft could operate, such as an airfield. Richard P. Hallion, *Taking Flight: Inventing the Aerial Age from Antiquity through the First World War* (New York: Oxford University Press, 2003), 146.
[6] Quote in Hansen, *Wind and Beyond*, 89.
[7] Crouch, *Dream of Wings*, 138; quote, 139.
[8] Rumerman, "Efforts at Powered Flight"; Crouch, *Dream of Wings*, 130, 151-52; quote, Hansen, *Wind and Beyond*,

make the flight results known in popular and technical publications throughout the United States and Europe. In a letter to Langley, Bell wrote:

> It seems to me that what I have been privileged to see today marks such a great progress on everything ever before done in this way that the news of it should be made public, and I am happy to give my own testimony on the results of two trials, which I witnessed today by your invitation hoping that you will kindly consent to making it known.[9]

Bell's letter describing the event was circulated to various journals and "[t]he resulting impact on both public and professional attitudes was enormous."[10] Overall, these flights "marked the end of an epoch in the history of flight." For the first time a large unpiloted, engine-driven, heavier-than-air flying model with a self-contained power plant had flown.[11]

Six months later, on November 28, 1896, *Langley Aerodrome No. 6*, powered by a one-horsepower steam engine, flew over 1,000 feet farther than *No. 5*. It had no method of steering and the wings were tilted upward so that the craft was dynamically stable and could right itself if disturbed by a sideways breeze. Government officials at the scene were impressed and, in 1898, the U.S. War Department appropriated $50,000 toward a manned aerodrome for the Spanish-American War, allowing Langley to continue with his work.[12]

In 1901, Langley progressed to a gasoline-powered miniature version of his model known as the *Langley Quarter Scale Aerodrome*. It was powered by a 1.5-horsepower internal combustion engine designed and built by inventor Stephen M. Balzer. On June 18, 1901, the model flew two flights with the longest being 350 feet. Balzer increased the engine capacity to just over three-horsepower resulting in an August 8, 1903, flight of 1,000 feet. Based on this aerodrome model, Langley proceeded to a full-size airplane. Completed in 1903 and weighing 750 pounds with the pilot on board, *Langley Aerodrome A* spanned nearly 50 feet, and was over 52 feet long. The craft's 52.4-horsepower five-cylinder air-cooled engine was built by Balzer, and later converted to a water-cooled radial by engineer Charles Manly, Langley's assistant. The first of its kind, "[t]here can be no doubt that the Manly-Balzer engine was the most advanced lightweight internal combustion engine in the world, but its utility as a power plant for the great aerodrome remained to be demonstrated."[13]

Langley decided, again, to fly over water for safety reasons. Because the first houseboat was no longer usable, he spent close to half his funds on a bigger houseboat and catapult that he kept at the Washington Navy Yard. On October 7, 1903, the launch catapulted the aerodrome with Manly piloting. In just 70 feet, Manly had to attain 60 miles-per-hour flying speed. The results

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146, from Bell's letter in *McClure's Magazine* 9 (June 1897): 659, published as "The Aerodromes in Flight," *Aeronautical Annual* (1897): 140-41.

[9] Crouch, *Dream of Wings*, 153.

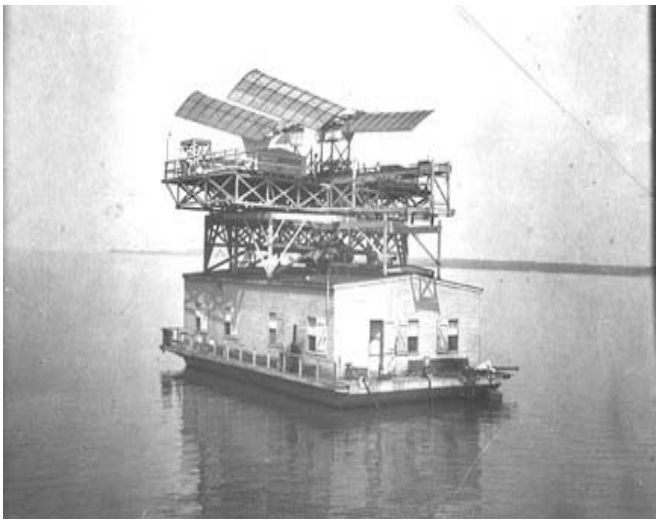
[10] Ibid., 154.

[11] Quote, Ibid., 152; Smithsonian National Air and Space Museum, "Langley Aerodrome No. 5," http://www.nasm.si.edu/research/aero/aircraft/langley5.htm (accessed November 10, 2004).

[12] Rumerman, "Efforts at Powered Flight." The craft flew 4,790 feet. Smithsonian National Air and Space Museum, "Langley Aerodrome No. 6," http://www.nasm.si.edu/research/aero/aircraft/langley6.htm (accessed November 10, 2004).

[13] Smithsonian National Air and Space Museum, "Langley Quarter Scale Aerodrome," http://www.nasm.si.edu/research/aero/aircraft/langley.htm (accessed November 10, 2004); Smithsonian National Air and Space Museum, "Langley Aerodrome A," http://www.nasm.si.edu/research/aero/aircraft/langleyA.htm (accessed November 10, 2004); quote, Crouch, *Dream of Wings*, 279.

were catastrophic as the wood-and-fabric aircraft broke without achieving any lift at all, plunging into the Potomac River. A Washington reporter on the scene remarked that the craft fell into the river "like a handful of mortar."[14]



Langley's Aerodrome A *aboard launch on houseboat. Source: Judy Rumerman, "Efforts at Powered Flight During the Last Decade Before the Wright Brothers," http://www.centennialofflight.gov/essay/Prehistory/Last_Decade/PH5.htm, U.S. Centennial of Flight*

Manly escaped injury and the Smithsonian crew repaired the aerodrome for a second test. The next attempt took place on December 8, 1903, at the confluence of the Potomac and Anacostia rivers. As before, the craft collapsed during launch and Manly nearly lost his life. The aerodrome simply lacked the structural changes needed to give the craft the control or strength necessary for its greater size. Langley's failure also stemmed from the fact that he had not conducted actual gliding experiments to determine the problems of sailing in the air. He had also not been methodical in testing each aspect of flight. Following the disastrous launch, the media and Congress attacked Langley for wasting its financial investment. Under intense ridicule, Langley officially ended the aerodrome project. Government funds directed toward aviation ceased and it would be thirteen years before a governmental advisory committee or aeronautical board would again come into existence.[15]

While Langley's final attempts at flight ended in disaster, aerospace historian James Hansen acknowledged the overall significance of Langley's work. "[H]is publications, beginning with his 1891 book *Experiments in Aerodynamics*, inspired others to step up their experimental efforts and to be systematic in carrying them out. Second and perhaps even more importantly, the fact that one of the greatest scientists in the country had decided to devote his efforts to the problems of flight convinced a great number of people that 'aeronautics was no longer the past-time of fools'."[16]

Octave Chanute

Like Langley, Octave Chanute, a self-taught civil engineer, also made outstanding contributions to early aviation. His emphasis on collaboration "helped move the leadership in aviation from

[14] Rumerman, "Efforts at Powered Flight"; Crouch, *Dream of Wings*, 266 for reference to Washington Navy Yard, 287 for mortar quote citing *Washington Post*, October 8, 1903.
[15] Congress passed enabling legislation for the National Advisory Committee for Aeronautics (NACA) on March 3, 1915, "to help the United States return to preeminence in aeronautics." Valerie Moolman, *The Road to Kitty Hawk*, rev. ed. (Alexandria, VA: Time-Life, 1981), 149; Rumerman, "Efforts at Powered Flight"; Roger D. Launius, "The Evolution of Flight," in *Reconsidering a Century of Flight*, ed. Roger D. Launius and Janet R. Daly Bednarek (Chapel Hill: University of North Carolina Press, 2003), quote, 56-57.
[16] Hansen, *Wind and Beyond*, 12.

Europe to the United States."[17] Working with colleagues, he produced an advanced biplane glider that became "the most significant and influential aircraft of the pre-Wright era" and "inadvertently created the first international aviation community, a creation leading to the successful invention of the airplane."[18]

Creating an International Aviation Community, 1885-1893

Chanute, who was born in France, came to the United States at the age of six. He became a civil engineer well-known for his original designs and construction of complex bridges and railroad terminals. His interest in aeronautics began in 1875 while vacationing in France. There he learned that an English engineer had developed the first "wind tunnel." Chanute thought this tunnel would benefit understanding of the destructive effects of high winds on bridges and certain roof designs.[19] At the same time, he became more convinced of the possibility of heavier-than-air flight. His own work originally kept him from devoting time to the topic but, in 1885, he began reviewing literature on flying machines. Chanute's belief in shared cooperation began one year later in 1886 at the Buffalo meeting of the American Association for the Advancement of Science. As vice president of the organization, he was influential in adding an aeronautical experimenter to the program. Unfortunately, the speaker was ridiculed. However, one attendee, Samuel Pierpoint Langley, came away from the meeting with the intent of proving or disproving the possibility of manned flight. That same year, Chanute began to research articles on aeronautical activity worldwide. In recognition of Chanute's growing knowledge, an engineering acquaintance and a technical journalist asked him to prepare a series of articles on the history of the flying machine. He accepted and at once began to communicate with aviation pioneers, making him "a clearinghouse for information within the community of aeronautical investigators."[20]

Chanute's findings and contact with European experimenters gave him the confidence he needed to publicly express his own belief in the possibility of flight. After retiring from engineering in 1889 at age 57, Chanute started his second career as an "aeronautical historian and champion of aviation." That year, he made presentations at a conference in Paris and at the Toronto meeting of the American Association for the Advancement of Science, and, in 1890, at Cornell University's Sibley College of Engineering. The extent of his knowledge and his engineering reputation gave credibility to his own presentations and" significant respectability" to aeronautics. Beginning in October 1891, the *Railroad and Engineering Journal* began publishing Chanute's series of 27 articles entitled "Progress in Flying Machines."[21]

At the World's Columbian Exposition in Chicago, Chanute became involved in the highly successful International Conference on Aerial Navigation held on August 1-4, 1893. The Pittsburgh *Dispatch* noted that the conference "marks a new era in aeronautics…and is no longer to be considered the hobby of mere cranks." In 1894, Chanute's 27 articles were compiled in the book, *Progress in Flying Machines*. This marked him "as the international authority on the

[17] U.S. Centennial of Flight Commission, "Octave Chanute—A Champion of Aviation," http://www.centennialofflight.gov/essay/Prehistory/chanute/PH7.htm (accessed October 8, 2004).
[18] Quotes, ibid., 17 and Hansen, *Wind and Beyond*, 17.
[19] Tom Crouch, *The Bishop's Boys: A Life of Wilbur and Orville Wright* (New York: W. W. Norton & Company, 1990), 149.
[20] Crouch, *Dream of Wings,* 26-27, 37, 41, 61-62, 76.
[21] Ibid., 73-75; quotes, U.S. Centennial of Flight Commission, "Octave Chanute."

history, theory, and current status of aeronautical studies." Decades later this book "remains one of the most comprehensive and reliable histories of pre-Wright aeronautics available."[22]

Experiments in Gliding, 1894-1896

In 1894, Chanute began conducting his own experiments using Lilienthal-type gliders. Otto Lilienthal, a German mechanical engineer, began studying aeronautics in 1879 and, through the 1880s, devoted himself to the study of aerodynamic principles with his work on unmanned gliders in Germany. In 1891, he became famous for his manned glider flights, eventually making around 2,000 glides. Lilienthal became known as the "Flying Man" and "was one of the most inspiring aviation pioneers of the late nineteenth century." In 1896, he died in a crash landing. Although others had flown in gliders previously, Lilienthal was the first to persist.[23]

Chanute spent the next few years designing and building gliders. Augustus M. Herring, a civil and mechanical engineer who brought with him the remains of a Lilienthal glider he had worked on, and William Avery, a carpenter in Chanute's neighborhood, assisted him. Paul Butusov, an immigrant Russian seaman who had approached Chanute with claims of secret glider flights in Kentucky, also provided assistance.[24]

In 1896, Avery's workshop produced two gliders—Herring's refurbished Lilienthal glider and a new glider named the *Katydid,* featuring multiple wings that could be moved about on the fuselage to facilitate experimentation. On June 22, Chanute and his assistants arrived on the shores of Lake Michigan at Miller Beach, Indiana. Flights with both gliders proved disappointing; the longest glides were under 100 feet. On July 4, the men returned to Chicago.[25] Work then commenced on glider repair and building. Avery worked on the *Katydid,* while Butusov built his own glider—the *Albatross*. Herring and Chanute designed a new aircraft called the *Chanute-Herring Biplane* featuring the Pratt truss (patented in 1844 as a design for railroad bridges). The truss connected the two wings with vertical struts and crossed diagonal wires. The Wright brothers later used this system as a model in their gliders and first airplane.[26]

In mid-August 1896, Chanute and his assistants prepared for a second test with the three new gliders. To avoid the reporters they had encountered at their first trials, the group chose a new and more isolated location a few miles from Miller Beach at Dune Park. Chanute chartered a ship, the *Scorpion,* to transport the men and machines to the test site. On August 20, the *Scorpion* picked up the *Katydid* and the Chanute-Herring glider at the Pestigo Dock on the Chicago lakefront, and the *Albatross* at the 71st Street pier. After an overnight stay, the party disembarked and pitched camp.[27]

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[22] Crouch, *Bishop's Boys,* 151-52, quoting from Pittsburgh *Dispatch,* January 23, 1984; Crouch, *Dream of Wings,* 76.

[23] Hansen, *Wind and Beyond,* 15-16, 91.

[24] U.S. Centennial of Flight Commission, "Octave Chanute"; Crouch, *Bishop's Boys,* 153-54. Herring would leave Chanute in the last half of 1895 to work briefly on Langley's aerodrome program at the Smithsonian. Butusov "had approached Chanute about working for him in exchange for funds to rebuild the glider that Butusov said he had flown in Kentucky in 1889." U.S. Centennial of Flight Commission, "Octave Chanute."

[25] Crouch, *Dream of Wings,* 181, 186, 189-90; Crouch, *Bishop's Boys,* 154. The *Katydid* was named for its insect-like appearance. Hansen, *Wind and Beyond,* 19.

[26] U.S. Centennial of Flight Commission, "Octave Chanute"; National Air and Space Administration, "The Origins of the First Powered, Man-carrying Airplane," http://www.quest.arc.nasa.gov/aero/wright/background/origin.html (accessed November 4, 2005). Controversy surrounded how much Herring and Chanute each contributed to the aircraft's design. Crouch, *Dream of Wings,* 192-94.

[27] Crouch, *Bishop's Boys,* 156; Crouch, *Dream of Wings,* 195.

Flight testing began on August 29. The *Katydid* and the *Albatross* proved inferior to the new Chanute-Herring glider. At first flying with three wings, the glider was found to be unwieldy. Removing the bottom wing greatly improved its gliding ability. Eventually the biplane glided 359 feet, surpassing gliders built by Lilienthal. Chanute's "experiments with gliders contributed to the science of flight, the areas of control systems and stability, efficiency of materials, and aircraft structural integrity and strength." "More than any other figure," Tom Crouch noted, "Chanute was responsible for propelling American aeronautics from folk technology to the status of an engineering discipline. In so doing, he had set in motion a chain of events that led to the triumph of December 17, 1903" by the Wright brothers.[28]

The Chanute camp on the Indiana dunes (1896). Source: "Octave Chanute—A Champion of Aviation," http://www.centennialofflight.gov/essay/Prehistory/ Chanute/PH7.htm, U.S. Centennial of Flight

Wright Brothers

In 1896, three pivotal events in aeronautical history occurred. That year, German engineer Otto Lilienthal died in a glider accident, thus "ending the most promising aeronautical activity up to that time;" Samuel Langley flew his aerodromes, showing "the technical feasibility of heavier-than-air powered flight;" and the Wright brothers began their "quest for manned flight." The earlier work done by pioneers such as Chanute, Lilienthal, and Langley had established the "first period of serious active aeronautical endeavor" that gave the Wrights their starting point.[29] Despite lacking high school diplomas, the brothers decided "to take a crack at inventing the airplane." In doing so, they "brought not only fresh perspectives and new energy to the fledgling field of flight research, but also one of the most remarkable collaborations of genuine talent in the history of invention."[30]

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[28] Crouch, *Bishop's Boys*, 156; quotes, U.S. Centennial of Flight Commission, "Octave Chanute" and Crouch, *Dream of Wings*, 22.
[29] John D. Anderson, Jr., *A History of Aerodynamics and Its Impact on Flying Machines* (Cambridge: Cambridge University Press, 1997), 201; Crouch, *Dream of Wings*, 228-29.
[30] Hansen, *Wind and Beyond*, 21.

1899 Kite

While manufacturing and repairing bicycles at their shop in Dayton, Ohio [Wright Cycle Company and Wright and Wright Printing, NHL, 1990; Dayton Aviation Heritage NHP, 1992], the Wright Brothers had gained valuable experience with diverse machinery. Looking for a new challenge, the brothers became intrigued by the advances early pioneers had made in regard to manned flight.[31] After they exhausted resources at the local library, they wrote to the Smithsonian Institution on May 30, 1899, requesting aviation materials and recommended publications. Langley's administrative assistant sent them important articles and advised them on how they could obtain Langley's *Experiments in Aerodynamics,* Chanute's *Progress in Flying Machines,* and James Means's *Aeronautical Annuals,* a series published to encourage interest in aviation and lessen rivalry between aeronauts.[32] After reviewing the literature, the brothers realized that the most important problem blocking successful flight was the ability to control and balance the craft. To solve the problem, Wilbur developed the concept of "wing-warping," whereby the wings twisted in opposite directions resulting in one wing lifting while the other lowered.[33] The Wrights tested the concept with their first aeronautical craft, a five-foot-wingspan biplane kite flown by Wilbur in late July 1899. The 1899 kite's successful performance prompted the brothers to design a glider based on the same ideas.[34]

Kitty Hawk and the 1900 Glider

In May 1900, as plans for their first glider [Wright 1900 Glider] commenced, Wilbur Wright wrote to Octave Chanute to introduce himself and his brother. The resulting relationship proved to be especially fruitful, with Chanute becoming a mentor to the Wrights. The glider plans produced a full-size, man-carrying aircraft, with two sets of wings positioned one above the other, a framework that allowed wing-warping, and an elevator in front of the wings that controlled the pitch (or angle) of the aircraft.[35]

After writing the U.S. Weather Bureau, the Wrights selected Kitty Hawk, North Carolina, as the new glider's test site because of its "steady winds, gently rolling sand slopes, and isolation." At the time Kitty Hawk "included a church, a store, and a handful of unpainted frame houses. A U.S. Weather Bureau facility and life-saving station rounded out the place." Chanute himself described the site in a paper he gave in London eight years later as being "situated on a long sand spit, two or three miles wide, between the waters of Pamlico Sound and the Atlantic Ocean. It is about as inaccessible a spot near civilisation [sic] as can well be, being almost a desert, occupied by a few fishermen and a Government lifesaving station. Near the camp is 'Kill Devil Hill,' a cone of drifted sand about 100 feet high, on which former gliding experiments were made."[36]

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[31] Crouch, *Dream of Wings,* 227.

[32] Smithsonian National Air and Space Museum, "Wright 1903 Flyer," http://www.nasm.si.edu/research/aero/aircraft/wright03.htm (accessed November 17, 2004); Crouch, *Dream of Wings,* 228. Means's magazine included contributions by aviation experimenters and historically important works on aviation. Only three issues appeared between 1895 and 1897. For further details, see Crouch, 105-07.

[33] U.S. Centennial of Flight Commission, "The Wright Brothers' 1900 Kite and Glider Experiments," http://www.centennialofflight.gov/essay/Wright_Bros/1900_Gliding/WR2.htm (accessed November 15, 2004); Crouch, *Dream of Wings,* 228-29. Unbeknownst to the Wrights, an earlier kite employing the wing-warping technique had been developed by Edson Gallaudet, a Johns Hopkins Ph.D. and physics instructor at Yale. In 1898 the kite flew in New Haven, Connecticut, and was donated to the Smithsonian in June 1921. The kite was "the first in the world to embody the wing-warping principle that would lead others to success." Crouch, *Dream of Wings,* 230-32.

[34] Smithsonian National Air and Space Museum, "Wright 1903 Flyer"; Crouch, *Dream of Wings,* 232-33.

[35] Smithsonian National Air and Space Museum, "Wright Brothers' 1900 Kite."

[36] Crouch, *Dreams of Wings,* 235-36; Hansen, *Wind and Beyond,* 231. Chanute statement is an excerpt from

Wilbur proceeded to Kitty Hawk on September 6, 1900, and arrived in Kitty Hawk Bay on September 12. He initially stayed at the two-story frame home of Currituck County commissioner William Tate. Orville arrived on September 20, and also stayed with the Tates until October 4, when he and Wilbur pitched camp a half mile away in a 12-by-22-foot tent. In following years they moved four miles down the beach to Kill Devil Hills. The 1900 flying season was a disappointment. Unmanned gliders were sent aloft and the lift and drag from scales on the kite lines were measured. For the next flying season, the brothers planned to build a larger glider based on the same plan but, as they told Chanute in May 1901, one that "will be larger and of improved construction in its details."[37]

1901 Glider

The new glider's [Wright 1901 Glider] wing surface was almost twice the area of the 1900 glider making it "the largest glider anyone had attempted to fly." With the start of the second flying season in July 1901, the Wrights began building a larger hangar to fit the new glider.[38] Gliding commenced on July 27. Even with a flight covering 335 feet (ending with a nose-first dive), these early flights were disappointing. Control was still a problem and the brothers began questioning the accuracy of the lift and drag data published by Lilienthal and John Smeaton (an eighteenth century British engineer) which they had used when designing their craft. They concluded their tests in mid-August. At this critical juncture, the Wrights decided to test Lilienthal's tables. Over the next months, they conducted a series of tests on wing shapes that would enable them to gather their own engineering data. Model airfoils attached to bicycles proved the tables were inaccurate. The brothers then built a wind tunnel that "measured coefficients of lift and drag on small model wing shapes" and, in just one day, they realized concerns about the data were justified.[39] While Lilienthal's tables were correct, Smeaton's coefficient was not. A second larger wind tunnel produced the critical data the Wrights would use for their 1902 glider.[40]

Some of the work leading to their next glider took place in the family home at 7 Hawthorne Street. In a letter to their father, Bishop Milton Wright, on August 20, 1902, Wilbur and Orville's sister, Katharine described her brother's activities at the house: "Will spins the sewing machine around by the hour while Orv squats around marking the places to sew. There is no place around the house to live."[41]

"Recent Aeronautical Progress in the United States," London, 1908.

[37] Crouch, *Dream of Wings,* 236, 238; Crouch, *Bishop's Boys,* 187, 188; Moolman, *Road to Kitty Hawk,* 224, 114. Quote, Crouch, *Dreams of Wings,* 239 from W. Wright to Chanute, May 12, 1901, Box 5, Chanute Collection. Plans for the 1902 glider were made in their workshop over the store. Moolman, *Road to Kitty Hawk,* 117.

[38] U.S. Centennial of Flight Commission, "Further Gliding and Wind Tunnel Experiments—1901," http://www.centennialofflight.gov/essay/Wright_Bros/1901/WR3.htm (accessed November 15, 2004); Crouch, *Dream of Wings,* 239, quote, 242.

[39] Smithsonian National Air and Space Museum, "Wright 1903 Flyer" for quoted language. For details, see Smithsonian National Air and Space Museum, "The Wright Brothers: The Invention of the Aerial Age," http://www.nasm.si.edu/wrightbrothers/fly/1900/designing.cfm. An airfoil is any part of an aircraft that is designed to produce lift. For aviation definitions, see U.S. Centennial of Flight Commission, http:// www.centennialofflight.gov/essay/timeline/search_diction.cfm.

[40] Crouch, *Dream of Wings,* 246-47; Moolman, *Road to Kitty Hawk,* 125.

[41] Crouch, *Dream of Wings,* 250, quoted in K. Wright to M. Wright, August 20, 1902, Box 5, Wright Collection.

1902 Glider

The brothers returned to Kitty Hawk on August 28. This third season of flight tests would become "a threshold in the development of flight." Both Wrights set about repairing and expanding the hangar for the new larger glider. At 16 feet long, it weighed 112 pounds and had a wingspan of 32 feet (10 feet greater than the 1901 glider), and twin rudders to prevent the aircraft from skidding.[42] On September 19, test flights began and, over time, the Wrights made multiple flights and became familiar with their control system. On September 23, Orville crashed, but escaped unscathed. The crash occurred after the glider slipped in a turn, a recurring problem associated with the warping control. In rebuilding the glider, Orville concluded that the answer lay in changing the fixed double rudder into a single movable rudder. By the time the Wrights broke camp on October 28, they had made between 700 and 1,000 flights and succeeded with the "world's first practical, controllable glider," making glides longer than 500 feet and obtaining a record distance of 622 feet.[43] The rudder made the 1902 glider [Wright 1902 Glider] capable of being precisely balanced in flight. As the U.S. Centennial of Flight Commission describes:

> The elevator controlled pitch, turning the glider's nose up or down. The wing warping controlled roll, raising or lowering a wing; and the rudder controlled yaw, moving the nose left or right. The glider was the world's first aircraft with three-axis control—control around the longitudinal, lateral, and vertical axes—and was the heart of the Wrights' first pioneer 'flying machine' patent. This breakthrough was so basic every aircraft and spacecraft flying today still uses the same fundamental controls of roll, pitch, and yaw first developed by the Wright brothers.[44]

All the Wrights now needed for a powered aircraft was a propeller and an engine. For an engine the Wrights settled on acquiring a gasoline motor not exceeding 180 pounds and having at least eight horsepower. With these specifications in mind, Wilbur wrote to 10 engine manufacturers, but no manufacturer was able or willing to produce such an engine at a reasonable price. Undaunted, the brothers decided to build their own engine. Their mechanic, Charlie Taylor, then produced the prototype for the roughly 200 engines the Wrights built during their aviation careers. "We didn't make any drawings, Taylor remembered. One of us would sketch out the part we were talking about on a piece of scratch paper and I'd spike the sketch over my bench."[45]

In the meantime, work proceeded on the propeller. The brothers built a larger wind tunnel to test their theory that "a propeller was simply an airplane wing that turned on a spiral course rather than moving ahead."[46] The problem, the brothers later wrote, "became more complex the longer we studied it. With the machine moving forward, the air flying backward, the propellers turning sidewise, and nothing standing still, it seemed impossible to find a starting point from which to trace the various simultaneous reactions. Contemplation of it was confusing." In the bicycle

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[42] Quote, Hansen, *Wind and Beyond,* 208; Moolman, *Road to Kitty Hawk,* 128, 129; U.S. Centennial of Flight Commission, "Success! Orville's and Wilbur's 1902 Glider Flights," http://www.centennialofflight.gov/essay/Wright_Bros/flights/WR4.htm (accessed November 17, 2004).

[43] Crouch, *Dream of Wings,* 251-52; quote, U.S. Centennial of Flight Commission, "Success!"; Smithsonian National Air and Space Museum, "Wright 1903 Flyer" for number of flights.

[44] U.S. Centennial of Flight Commission, "Success!"

[45] U.S. Centennial of Flight Commission, "Before the First Powered Flight," http://www.centennialofflight.gov/essay/Wright_Bros/1903_Before_Flight/WR5.htm (accessed November 17, 2004); quote from Moolman, *Road to Kitty Hawk,* 138.

[46] U.S. Centennial of Flight Commission, "Before the First Powered Flight."

shop, they sometimes argued. Charlie Taylor described these arguments, saying, "I don't think they really got mad, but they sure got awfully hot."[47] Ultimately, in April 1903, they perfected "the world's first true aircraft propeller, a device whose performance could be precisely calculated."[48] The new airplane was their biggest, with a 40-foot wingspan and weighing 625 pounds. Orville referred to it as the "whopper flying machine."[49]

During this design phase, the Wrights unsuccessfully applied for a patent for a "Flying Machine." It turned out that the U.S. Patent Office had received so many applications over the last five decades that they automatically rejected any for craft that had not already flown. Another three years would pass before the Wrights obtained a patent.[50]

1903 Wright Flyer

After they arrived in Kitty Hawk on September 26, 1903, the brothers constructed a second building for a workshop and their aircraft. Engine problems delayed any attempts to fly for weeks. Finally, on December 14, they decided to make a test flight. Together with the crew of the nearby Kill Devil Lifesaving Station, the Wrights rolled the aircraft along a 60-foot rail they repeatedly re-laid to reach the bottom of the great dune.[51] Wilbur won the coin toss to pilot the airplane. He raced the machine down the track only to climb too steeply and stall, plowing into the sand and slightly damaging a wing, front rudder, and a landing skid.

Their next attempted flight came on December 17, yielding success. Orville flew the plane 120 feet in 12 seconds, and three more flights that day yielded a best distance of 852 feet for 59 seconds. "For the first time, a powered flying machine had taken off from level ground, traveled through the air, and landed under the control of its pilot." Life station observers and the brothers were carrying the machine back to the campsite when a wind gust lifted and rolled the plane, causing extensive damage. The 1903 flyer [Wright 1903 Flyer] was never flown again.[52] Later that day, the brothers proceeded to the lifesaving station to send a telegraph to their father: "Success four flights Thursday morning all against twenty-one mile wind started from level with engine power plane average speed through air thirty-one miles longest 57 seconds inform press home Christmas."[53]

Along with the telegram, the Wrights prepared "carefully worded statements" for the press, yet the press bungled and botched the story of the brothers' first success, a pattern that persisted for another five years. "One aviation historian, the distinguished Richard K. Smith, has gone so far as to say that 'the relationship between the Wrights and the news medium of their day is one of the most grotesque stories of the twentieth century and it was by no means the fault of the Wrights.'" Rather than accurately conveying the Wrights' description of events, journalists who

[47] Moolman, *Road to Kitty Hawk*, 140.
[48] Crouch, *Dream of Wings*, 294.
[49] U.S. Centennial of Flight Commission, "Before the First Powered Flight."
[50] Ibid.
[51] Moolman, *Road to Kitty Hawk*, 141, 150-52. The Wrights referred to the rail as "the Grand Junction Railroad." Crouch, *Bishop's Boys*, 265.
[52] Moolman, *Road to Kitty Hawk*, 153-54. The rail cost the Wrights $4.00 to build, while Langley's launching system cost nearly $50,000, and it failed. Crouch, *Dream of Wings*, 299. Hansen, *Wind and Beyond*, 29; quote, U.S. Centennial of Flight Commission, "The First Powered Flight—1903," http://www.centennialofflight.gov/essay/Wright/ Bros/First_Powered_Flight/WR6.htm (accessed November 17, 2004).
[53] Crouch, *Dream of Wings*, 305.

did follow the story wrote "imaginative, inaccurate accounts that disturbed the Wrights and misled the public." To some degree, this misrepresentation of the Wrights' flight should not have been surprising. Just days earlier the press had witnessed one of the nation's leading scientists fail to fly when Samuel Langley's full-scale aerodrome crashed into the Potomac River.[54]

Despite the media's misrepresentation of their flight, the Wrights' early work in experimental aircraft was decisive within aviation history. In the words of the Smithsonian National Air and Space Museum, the Wrights "pioneered many of the basic tenets and techniques of modern aeronautical engineering, such as the use of a wind tunnel and flight testing as design tools. Their seminal accomplishment encompassed not only the breakthrough first flight of an airplane, but also the equally important achievement of establishing the foundation of aeronautical engineering."[55]

Huffman Prairie and the 1904 Wright Flyer II

Back in Dayton, the brothers contrived to develop a practical airplane that could exceed the 1903 Kitty Hawk flights. They crated up the flyer and stored it in a shed behind their Dayton workshop. Deciding to carry on in the Dayton area, the brothers chose Huffman Prairie [Huffman Prairie Flying Field, NHL, 1990; Dayton Aviation Heritage NHP, 1992], eight miles east of Dayton on the DS & U trolley line, as their new flying field. The owner of the 100-acre pasture, Dayton bank president Torence Huffman, let the brothers use the field for free. Now the brothers could live at home, oversee the bicycle shop, and fly from the early spring to late fall at little expense.[56]

From a wooden hangar the brothers erected on the prairie, they built their Flyer II [Wright 1904 Flyer II]. This stronger and heavier aircraft used a more efficient 16-horsepower engine. Although it had an advanced design, the new flyer initially delivered disappointing performances. On May 23, 1904, the Wrights invited spectators, including newsmen, to come watch them fly. With no wind, the machine refused to launch. Following three days of rain, a handful of spectators returned to witness a hop of 25 feet. Unimpressed, they left the brothers alone. Now working in relative privacy, the Wrights continued with trial flights through the spring and summer. To compensate for light winds, they designed a catapult to get the craft to flying speed. First used on September 7, 1904, the catapult proved itself and by September 15, the Wrights lengthened their flights up to a half-mile and began making controlled turns.[57] On September 20, Wilbur flew the first circle with a flying machine, setting a distance record of about ¾ of a mile.[58]

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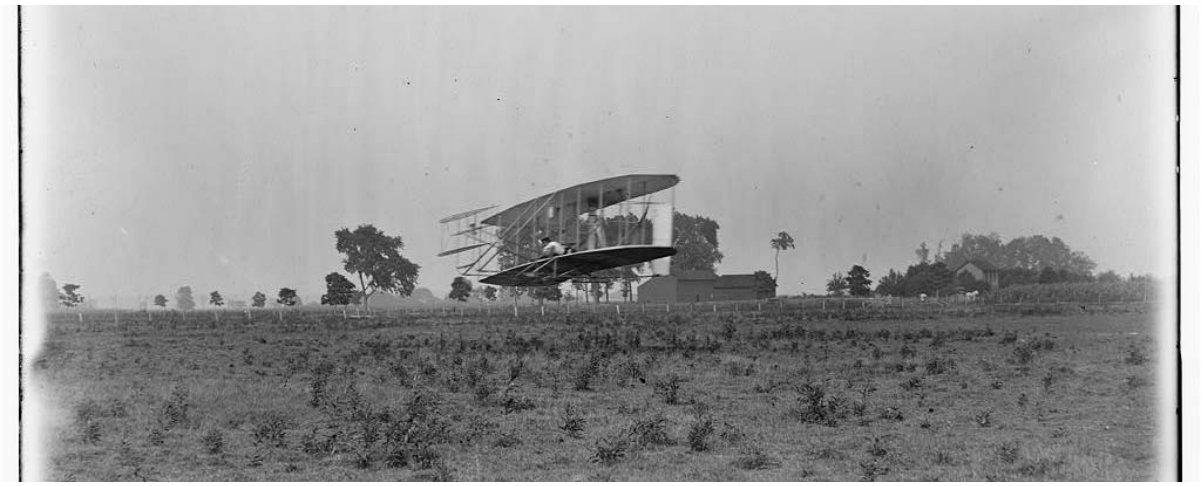
[54] Hansen, *Wind and Beyond*, 221. One newspaper, the *Dayton Press*, carried the Wright's full statement. Smith's statement taken from "Not a Success—But a Triumph: 80 Years since Kitty Hawk," *Naval War College Review* 36 (November-December 1983): 13.

[55] Smithsonian National Air and Space Museum, "Wright 1903 Flyer."

[56] Moolman, *Road to Kitty Hawk*, 145, 154; Crouch, *Bishop's Boys*, 278, 279; Tom D. Crouch, *Wings: A History of Aviation from Kites to the Space Age* (New York: W. W. Norton & Company, 2003), 80. Today the field is part of Wright-Patterson Air Force Base. DS & U stood for Dayton, Springfield, and Urbana interurban rail as supplied by historian Edward Roach of the Dayton Aviation Heritage National Historic Park.

[57] U.S. Centennial of Flight Commission, "Huffman Prairie—1904," http://www.centennialofflight.gov/essay/Wright_Bros/1904/WR7.htm (accessed November 17, 2004); Crouch, *Wings*, 80.

[58] Moolman, *Road to Kitty Hawk*, 158.



Orville Wright covers 356 feet on Flight 19 at Huffman Prairie on August 5, 1904. Source: Library of Congress, Prints and Photographs Division [LC-W86-26]

Witnessing this event was Amos Root, a beekeeper and publisher of *Gleanings in Bee Culture*. Readers of his journal were treated to "the first eyewitness account of an airplane in full flight." For the next two years, Root continued to write of the aerial achievements in the journal. Other media, however, chose not to cover the flights. Given, the spectacular failure of Langley's government-funded aerodrome in 1903, success from two little-known inventors seemed unlikely.[59]

Yet, in 1904, the Wrights made 105 flights. On November 9 and December 1, they achieved their two best flights. These were over five minutes and covered around three miles. However, problems continued to persist with control and the plane tended to swing up and down. Unable to resolve these problems, the brothers decided to redesign the plane.[60]

1905 Wright Flyer III

In May 1905, the Wrights began to build the new Wright Flyer III [NHL, 1990; Dayton Aviation Heritage NHP, 1992]. Based on the same design as the Flyer II, it had a new airframe along with the salvaged engines, propellers, and hardware from the Flyer II. Improvements gave this craft better pitch and yaw control and the pilot had full control of the rudder. Flying commenced on June 23 with disappointing results culminating in a drastic and almost fatal crash on July 14, when Orville was thrown out through the top wing after smashing into the ground. After making major changes to the size and location of the elevator, they began flying again in late August. Their changes produced an airworthy craft. The brothers began flying multiple circuits around the field and landing safely. For the first time, on September 26, Wilbur flew for more than 18 minutes until the gas tank ran dry; Orville flew the longest flight on October 4, remaining in the air for 33 minutes.[61]

The next day, a small crowd gathered to watch the brothers fly. They were rewarded with the sight of Wilbur making the longest flight ever—30 circles in almost 39 minutes, covering 24

[59] Quote, ibid.; U.S. Centennial of Flight Commission, "Huffman Prairie"; Hansen, *Wind and Beyond*, 28.
[60] U.S. Centennial of Flight Commission, "Huffman Prairie."
[61] Judy Rumerman, "1905—The First Practical Airplane," http://www.centennialofflight.gov/essay/Wright_Bros/1905_Flyer/WR8.htm, U.S. Centennial of Flight Commission (accessed November 19, 2004).

miles before he ran out of gas. He was in the air longer than the combined 109 flights the brothers made in 1903 and 1904. The Wrights had invented "one of the most extraordinary machines in the history of technology."[62]

Unfortunately, Octave Chanute missed the chance to see the Wrights fly. At the brothers' urging, he made it to Dayton on November 1, but inclement weather deterred any flying.[63] With their practical flying machine in hand, the brothers made the extraordinary decision to end their flying experiments. On November 5, 1905, the brothers took apart the Flyer III. They would not fly again until 1908. Fearing publicity that could result in someone copying their plane's configuration, the Wrights focused on potential customers and securing a patent. Through their congressman, the Wrights first approached the U.S. War Department and received a negative response. They then approached the British and French military establishments. Unfortunately, their sales approach hindered any success in gaining a contract. To protect their future patent, they refused to demonstrate the aircraft without a signed contract, offering instead to release the buyers from the contract if the plane did not perform. Both the British and the French refused to buy "sight unseen." The French, in particular, found the $200,000 price tag too high.[64]

The next year, European skeptics in both the aviation community and the press questioned whether the Wrights could fly. In France, newspapers referred to the Wrights as *bluffeurs* (bluffers). An editorial in the Paris edition of the *New York Herald* stated on February 10, 1906: "The Wrights have flown or they have not flown. They possess a machine or they do not possess one. They are in fact either fliers or liars. It is difficult to fly. It's easy to say, 'We have flown.'" Meanwhile, back home, the American aviation and science community began to give some recognition to the brothers. The newly formed Aero Club of America recognized the Wrights' achievements in many newspapers. *Scientific American*, reversing its earlier published skeptical editorials, stated that the Wrights "deserve the highest credit for having perfected the first flying machine."[65]

Both the brothers' delay in finding a buyer and their decision to stop flying gave other pioneering aviators the opportunity to not only catch up, as Octave Chanute predicted, but also surpass them. Along with the French, who regarded themselves as the leaders in world aviation, the Wrights faced competition in America. One of their future competitors, Glenn Curtiss, visited the Wrights in 1906. Curtiss had developed a dirigible balloon engine and would become an engine-builder in Alexander Graham Bell's Aerial Experiment Association. This was the first of the many times Curtiss and the Wright brothers would meet. On May 23, 1906, the Wright brothers received Patent No. 821,393 for a Flying Machine, an achievement that "would prove to be enormously significant in the development of future aircraft and the aviation industry."[66]

Getting into the Air, 1906-1909

After the Wrights invented the flying machine, Glenn Curtiss became the brothers' primary competitor. A motorcycle racer and engine builder, Curtiss joined the Aerial Experiment

[62] Ibid.; quote, Crouch, *Bishop's Boys*, 299.
[63] Rumerman, "1905."
[64] Ibid.; R. G. Grant, *Flight: 100 Years of Aviation* (New York: Dorling Kindersley Publishing, 2002), 30; Phillip S. Meilinger, "Significant Milestones in Air Force History" (Air Force History and Museums Program, 2003), 1.
[65] U.S. Centennial of Flight Commission, "Europe Spreads Its Wings," http://www.centennialofflight.gov/essay/Wright_Bros/1906/WR9.htm (accessed November 17, 2004).
[66] Ibid.

Association (AEA) in 1907, designing and building four "dromes" that gained the group world prominence. Beginning in 1909, Curtiss's pusher biplane designs were among the most successful and important aircraft of the period. However, his first aircraft sparked a notorious multi-year patent dispute with the Wright brothers which delayed the production and selling of U.S. aircraft. During the litigation, both Curtiss and the Wrights competed in airshows and conducted flying schools. Although Curtiss sold the first airplane in the United States in June 1909, the Wrights sold the U.S. Army the world's first military airplane only two months later. One of the founding fathers of American aviation, Curtiss made the first public flight in the United States, pioneered seaplane designs, and became the leading aircraft manufacturer in the country by 1914.[67]

Glenn Curtiss

Glenn Curtiss, like the Wrights, started out building bicycles from his shop on Pulteney Street in Hammondsport, New York. Curtiss had grown up in Hammondsport in a home called Castle Hill, which he later inherited and where he did much of his work. Curtiss moved from building bicycles to building motorcycles in 1902, and the firm became known as the G. H. Curtiss Manufacturing Company. A workshop annex was built on the back of the store and barn which Curtiss later referred to as his "industrial incubator." Known as "the hell-rider," Curtiss became a record-setting motorcycle racer winning his fame and advertising for his motorcycles and their powerful, lightweight engines. With more orders arriving, Curtiss built a new motorcycle plant adjacent to his home in 1904, starting with a two-story, 60-by-20-foot building. Two more buildings followed in 1905 and 1906 respectively. On October 19, 1905, Curtiss filed incorporation papers for his manufacturing business.[68]

Curtiss's association with aviation began to take shape in 1904 when Thomas Baldwin ordered a two-cylinder motorcycle engine for his *California Arrow*, the first successful dirigible to fly in the United States. In January 1906, Curtiss exhibited his dirigible balloon engines in the Aero Club of America's first annual aeronautical show held as part of the annual Automobile Show in New York City.[69] A speaker at the show, inventor Alexander Graham Bell, saw Curtiss's exhibit and, after returning to his Nova Scotia summer home, promptly ordered a Curtiss engine for propeller experiments he was conducting on a catamaran boat.[70] Bell also asked Curtiss to join a new think tank, the Aerial Experiment Association (AEA). The group included four aviation enthusiasts whom Bell had gathered to build a practical airplane using $20,000 contributed by his wife, Mabel. Bell was the chairman of the group, which was formed in Canada on September 30, 1907. Curtiss served as director of experiments and chief executive officer. Other members included Bell's two assistants, F. W. Baldwin and J. A. D. McCurdy, and Lt. Thomas E. Selfridge. Baldwin became chief engineer, McCurdy was assistant engineer and treasurer, and Selfridge was secretary.[71] According to the articles of agreement, Bell agreed to assist "these gentlemen in carrying out their own independent ideas relating to aerial locomotion, and all working together individually and conjointly in pursuance of their common aim 'to get into the

[67] C. R. Roseberry, *Glenn Curtiss: Pioneer of Flight* (Syracuse: Syracuse University Press, 1991), 2.
[68] Roseberry, *Glenn Curtiss*, 22, 25, 31, 32, 34; Walter J. Boyne, *The Smithsonian Book of Flight* (New York: Orion Books, 1987), 59. At his home, in 1906, Curtiss constructed a cupola called The Annex from where he worked. He designed the cupola to have access only from a stairway off the side porch. Roseberry, *Glenn Curtiss*, 46.
[69] The Aero Club had formed in 1905 as an offshoot of the Automobile Club of America.
[70] Boyne, *Smithsonian Book of Flight*, 43; Roseberry, *Glenn Curtiss*, 35, 40, 48-49.
[71] Vern Renaud and Fred Wolff, "Hell Rider: The Glenn Curtiss Story," *Aviation Quarterly* 1, no. 5 (1979): 33, 37; Boyne, *Smithsonian Book of Flight*, 59.

air' upon the construction of a practical aerodrome driven by its own motive [sic] power and carrying a man."[72]

During the summer and fall of 1907, at Bell's Nova Scotia home, they conducted experiments with powered kites and aerial propellers. During warmer weather, they moved operations to Curtiss's factory site in Hammondsport. In January 1908, Selfridge contacted the Wrights, inquiring about aircraft construction. Because the Wrights respected Bell, they felt safe from patent infringement. They referred Selfridge to other publications and to their 1906 patent that embodied the control features of their 1902 glider. It described wing warping and also stated "that a feature like ailerons could provide lateral control."[73]

AEA Dromes, 1908

Selfridge designed the first of the AEA "dromes" and named it *Red Wing* because of its red cloth wing covering. In the winter of 1908, Curtiss tested the motor and propeller for the *Red Wing* with his ice-cycle on frozen Keuka Lake. As the Curtiss plant had reached its capacity, *Red Wing* was built in the aerodrome shed "erected down on the Kingsley Flats, near the lakefront east of town," a cow pasture that served as a baseball field in the summer.[74] *Red Wing* looked similar to a Wright biplane. However, it differed in two respects: elevators were located at both the front and back of the craft, and the lower and upper set of wings were curved with trusses so they almost touched. No wing warping was employed. On March 12, 1908, *Red Wing* flew at an altitude of about 200 feet over a distance of 319 feet before crashing.[75]

Baldwin designed the AEA's second plane named *White Wing*. Unlike *Red Wing*, it contained wheels instead of sled runners and included small ailerons (an alternative to wing warping) at the upper wingtips for lateral control. On May 17, at the Stony Brook racetrack near Hammondsport, Baldwin flew *White Wing* for 285 feet. The next day Selfridge flew two flights at 100 feet and 240 feet. On May 21, Curtiss flew for 1,017 feet. Unfortunately, McCurdy flew for 720 feet and wrecked the plane on landing.[76]

Curtiss designed drome No. 3, the *June Bug*, an aircraft that "catapulted the AEA and Curtiss into world prominence." Curtiss first flew the *June Bug* on June 21, 1908, flying more than 3,000 feet. With this accomplishment, the group decided to compete for the *Scientific American* trophy sponsored by the *Scientific American* magazine and the Aero Club of America. To gain permanent possession of the trophy, the first American reward ever offered in the aviation community, a pilot had to win the trophy at least once in three different years. Each year the feat to win the trophy was based on the advances made in aviation. For this first trial, a plane had to fly a kilometer (3,168 feet) in a straight line.[77]

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[72] Roseberry, *Glenn Curtiss*, 78.
[73] Renaud and Wolff, "Hell Rider," 33, 37; Crouch, *Bishop's Boys*, 349, 352; quote, U.S. Centennial of Flight Commission, "Glenn Curtiss and the Wright Patent Battles," http://www.centennialofflight.gov/essay/Wright_Bros/Patent_Battles/WR12.htm (accessed November 17, 2004). AEA members were known as "Bell's Boys." Crouch, *Dream of Wings*, 296.
[74] U.S. Centennial of Flight Commission, "Glenn Curtiss and the Wright Patent Battles"; Roseberry, *Glenn Curtiss*, 90.
[75] U.S. Centennial of Flight Commission, "Glenn Curtiss and the Wright Patent Battles." *Red Wing* was tested "on a smooth patch of ice five miles from Hammondsport." Crouch, *Bishop's Boys*, 353.
[76] U.S. Centennial of Flight Commission, "Glenn Curtiss and the Wright Patent Battles"; Crouch, *Bishop's Boys*, 353.
[77] Boyne, *Smithsonian Book of Flight*, quote, 61; U.S. Centennial of Flight Commission, "Glenn Curtiss." The

The AEA chose Hammondsport as the flight site. The Aero Club contacted the Wrights and offered to delay the competition in hopes they would enter. To compete, the Wrights would have to put wheels on their plane and use a field large enough for an unassisted takeoff run. However, the Wrights had no interest "in competing with latecomers who were infringing on their patents." On July 4, Curtiss captured the trophy, flying 5,360 feet in one minute and forty seconds.[78] The win placed Curtiss on a par with the Wrights.[79] Orville Wright now warned Curtiss that he did not have permission to use their control system for either exhibitions or commercial use.[80]

The AEA then built their last and most successful aircraft, the *Silver Dart*. McCurdy flew this in Hammondsport in December 1908. The *Silver Dart* became the first plane flown in Canada (it was later wrecked in August 1909). The group disbanded after having achieved their goal of building a practical aircraft. Earlier, in November 1908, Bell's attorney had supplied a proposed patent application for the Hammondsport planes, titled "New and Useful Improvement in Flying Machines," listing 28 innovations. These included Bell's ailerons, although they were referred to as "lateral balancing rudders" in the application. The patent was granted December 5, 1911.[81]

The *Golden Flyer* and the *Reims Racer*, 1909

Curtiss's success in winning the *Scientific American* trophy sparked the Aeronautical Society of New York City to ask Curtiss for a plane and flight instruction for two of its members. To fill the order, the Hammondsport facility expanded and Curtiss entered into a short-lived partnership with Octave Chanute's former associate, Augustus M. Herring. Formation of the Herring-Curtiss Company in March 1909 and the society's purchase of the plane for $5,000 produced two aviation "firsts" in the United States: the first actual aeroplane manufacturing firm, and the first sale of an airplane, the *Golden Flyer*, to a civil owner.[82]

On June 16, 1909, Curtiss flew the *Golden Flyer* at Morris Park in the Bronx, and on June 26 he flew his first circle before a crowd of 5,000 spectators. On July 17, he flew 25 miles from Mineola on Long Island to win the *Scientific American* trophy for the second time. Following this win, the Wrights filed suit against Curtiss and the Herring-Curtiss Company, arguing that Curtiss and the company had not obtained permission to use their lateral control and aileron design. Because the *Golden Flyer* had ailerons mounted between the biplane wings rather than as described in the Wright patent, Curtiss chose to contest the suit.[83]

After Curtiss delivered the *Golden Flyer* to the Aeronautical Society, the Aero Club of America chose Curtiss to be the only American participant in the first international aviation meet, La

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Scientific American was a weekly periodical plugging aeronautics. Roseberry, *Glenn Curtiss*, 103.

[78] U.S. Centennial of Flight Commission, "Glenn Curtiss and the Wright Patent Battles"; quote, Crouch, *Bishop's Boys*, 363. Only people at Huffman Prairie had ever seen the Wrights fly. Boyne, *Smithsonian Book of Flight*, 61. Two years later, the Aero Club would award Glenn Curtiss with License Number 1 based on this first public flight made in America by a U.S. citizen. Roseberry, *Glenn Curtiss*, 320.

[79] Boyne, *Smithsonian Book of Flight*, 62. It was also the first time a motion-picture camera filmed an aircraft.

[80] U.S. Centennial of Flight Commission, "The First Military Flyer," http://www.centennialofflight.gov/essay/Wright_Bros/Military_Flyer/WR11.htm (accessed November 17, 2004).

[81] U.S. Centennial of Flight Commission, "Glenn Curtiss and the Wright Patent Battles"; Roseberry, *Glenn Curtiss*, 143, 146, 285, 469. While granted in 1911, the patents were not issued until 1913 due to a "prolonged contest in the Patent Office." Roseberry, *Glenn Curtiss*, 348.

[82] Roseberry, *Glenn Curtiss*, 159; Renaud, "Hell Rider," 38; Smithsonian National Air and Space Museum, "Curtiss D-III," http://www.nasm.si.edu/research/aero/aircraft/curtiss_diii.htm (accessed April 2, 2005, since removed).

[83] U.S. Centennial of Flight Commission, "Glenn Curtiss and the Wright Patent Battles."

Grande Semaine d'Aviation (The Grand Week of Aviation). Held in Reims in August 1909, the event would establish "the credibility of heavier-than-air flight as a practical new technology." For this event, Curtiss flew his newly designed *Reims Racer*.[84] On August 28, 1909, Curtiss won the Gordon Bennett Aviation Cup for flying the fastest average speed of 47.6 miles per hour over a 12.5-mile closed course.[85] Later describing his flight, Curtiss stated: "The machine pitched considerably, and when I passed above the 'graveyard' where so many machines had gone down and were smashed during the previous days, the air seemed literally to drop from under me." He won $7,600 at Reims and continued on to another air meet in Brescia, Italy. There he won both the grand prize and the altitude prize along with another $7,000. Curtiss returned to the United States an international hero.[86]

After his return, Curtiss ended his partnership with Herring. Herring had not produced any of the working capital he had promised and Curtiss was facing mounting expansion costs, including over $18,000 for a new machine shop and other buildings. Lacking capital, the company went bankrupt on December 2, 1910. A day later, Curtiss formed the Curtiss Aeroplane and Motor Corporation. By the end of the year, however, the new factory closed. Later, with the onset of World War I, the Curtiss Company expanded operations to Buffalo and Garden City, Long Island. Eventually the Hammondsport plant shut down around 1920. Only a portion of one plant building remains today.[87]

Marketing the Flying Machine

Successful flying experiments by Curtiss in America and others in Europe pushed the Wrights to consummate deals for their flying machine in the winter of 1907-08. In France, the brothers had met Frank P. Lahm a lieutenant with the U.S. Army Signal Corps' new Aeronautical Division in "charge of all matters pertaining to military ballooning, air machines, and all kindred subjects."[88] Writing to his commander in early fall 1907, Lahm said that it was "unfortunate that this American invention, which unquestionably has considerable military value, should not first be acquired by the United States Army." Wilbur Wright met with the Board of Ordnance and Fortification at their December 1907 meeting, explaining what the plane could do and offering one for $25,000.[89]

Drawing on Wilbur's explanation, the U.S. War Department issued Specification No. 486 for a heavier-than-air flying machine. The request for proposals stipulated that the aircraft be capable of carrying two men for 125 miles at no less than 40 miles per hour. It also had to remain aloft for one hour, be capable of landing in an unprepared field, and land safely in the event of motor failure. All this was to be accomplished under perfect control and equilibrium. Although the *New York Globe* remarked that a feat of this type would probably be "the most epoch-making invention in the history of civilization," the press and aeronautical community were highly skeptical that such an aircraft could be produced. Reflecting this widespread skepticism, the editor of the *Aeronautical Annals* noted "that while Minerva sprang 'fully fledged from the head

[84] Smithsonian National Air and Space Museum, "Curtiss D-III"; quote, Grant, *Flight*, 43-44.
[85] U.S. Centennial of Flight Commission, "Glenn Curtiss and the Wright Patent Battles"; "Curtiss D-III."
[86] Quote, Grant, *Flight*, 46; Smithsonian National Air and Space Museum, "Curtiss D-III."
[87] The plant was used for other purposes over time. Roseberry, *Glenn Curtiss*, 178-79, 257-58, 394, 407, 420-30.
[88] A. Timothy Warnock, "The Wright Brothers and the U.S. Army Signal Corps, 1905-1915," in *Reconsidering a Century of Flight*, ed. Roger. D. Launius and Janet R. Daly Bednarek (Chapel Hill: University of North Carolina Press, 2003), 154.
[89] Crouch, *Bishop's Boys*, 341, quoting from Stephen F. Tillman, *Man Unafraid: The Miracle of Military Aviation* (Washington, DC: Army Times Publishing Co., 1958), 14-15; Warnock, "Wright Brothers," 154.

of Jupiter…I hardly think that the perfect flying machine will appear in such sudden fashion."[90] In a July 1908 article, Chanute agreed: "The public attitude in the United States in 1906 and 1907 concerning aerial navigation has been one of expectancy and apathy. The announcements of the marvelous success achieved by Wright Brothers, which every investigation seemed to confirm, must have deterred many searchers from experimenting at all, until they know how much remained to be accomplished in aviation."[91]

On January 27, 1908, the Wrights submitted their proposal to the War Department. They would earn an extra 10 percent for each full mile per hour exceeding 40, and be penalized likewise for each mile less. This was considerably less than the $200,000 they had sought from the French government the year before and $75,000 less than the Wrights' asking price a few months earlier when the U.S. Army had demanded exclusive rights. At that time, the Wrights had declined the Army's request because they had a commitment for aircraft from a French business group. Only one other bid from Augustus Herring at $20,000 was considered, but his plane never materialized.[92]

The Wrights and their mechanic, Charlie Furnas, returned to the privacy of Kitty Hawk in April 1908 with the refurbished 1905 flyer complete with upright seats and upright controls (for the new *Flyer A* configuration). After rebuilding their camp, they began flying on May 14, 1908, using a bag of sand as a passenger. Furnas became the Wrights' first airplane passenger. On the last solo flight, Wilbur and the plane crash landed. Although Wilbur was unhurt, the plane had to be rebuilt. The Wrights then decided to separate, with Orville staying in America to work on the army's plane and Wilbur traveling to France for the demonstration flights.[93]

On August 8, 1908, Wilbur finally flew in France, ending the criticism that had preceded his arrival. Ernest Archdeacon, an aviation backer and one of the Wrights' harshest critics, was present at this flight. Deeply impressed, Archdeacon reversed his former position, stating that "For too long, the Wright brothers have been accused of bluffing. They are hallowed today in France, and I feel an intense pleasure in counting myself among the first to make amends." After his triumphant flight, Wilbur continued flying over the next few months in France and, by January 2, 1909, he had established nine world records in distance, duration, and altitude.[94]

Fort Myer and the 1908 Flyer

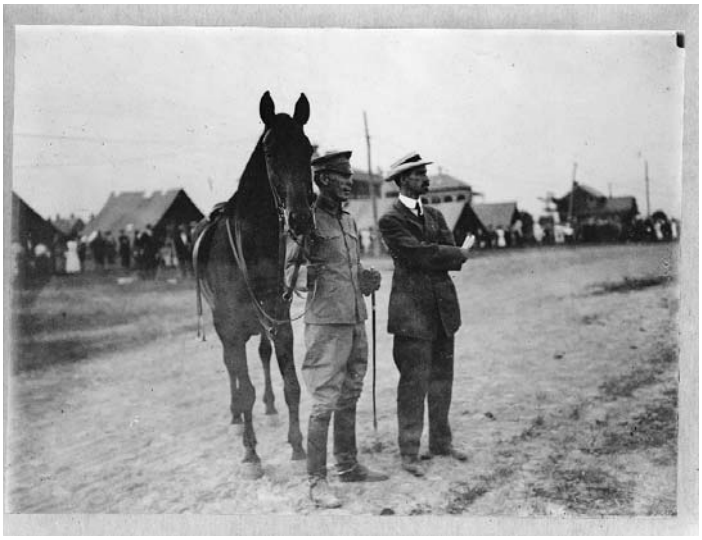
Back in America, Orville Wright and the army aircraft arrived at Fort Myer, Virginia, [Fort Myer Historic District, NHL] for the U.S. military trials in August 1908. Orville began flying on September 3, with a short flight on the parade ground. Over the next few days, he continued flying in front of a growing crowd. Each flight was longer than the last. On September 9, he embarked on what became a string of nine world records. On one flight he remained aloft for 70 minutes, 24 seconds; on another he carried a passenger for 9 minutes, 6 seconds. However, on

[90] Judy Rumerman, "Things are Looking Up," http://www.cetennialofflight.gov/essay/Wright_Bros/1907-08WR10.htm, U.S. Centennial of Flight Commission (accessed November 11, 2004); Warnock, "Wright Brothers," 154; Crouch, *Bishop's Boys,* 347, quoting from Tillman, *Man Unafraid,* 16, and from James Means to Octave Chanute, January 10, 1908, Octave Chanute Papers, Manuscript Division, Library of Congress.
[91] Hansen, *Wind and Beyond,* 229-30, quoting from Octave Chanute, excerpts from "Recent Aeronautical Progress in the United States," *The Aeronautical Journal,* London (July 12, 1908): 52-55.
[92] Rumerman, "Things are Looking Up"; Boyne, *Smithsonian Book of Flight,* 58; Warnock, "Wright Brothers," 153-54. The board received a total of 41 proposals. Crouch, *Bishop's Boys,* 348.
[93] Rumerman, "Things are Looking Up."
[94] Quote, ibid.; U.S. Centennial of Flight Commission, "First Military Flyer"; Crouch, *Bishop's Boys,* 380-81.

September 17 tragedy struck on the final preliminary flight when a crack in the propeller caused the plane [Wright 1908 Military Flyer] to crash. Orville was hospitalized for three months with serious injuries, but his passenger, Lt. Thomas Selfridge, died at the fort's hospital—the first passenger fatality in an airplane and a tragic loss for the AEA. Orville uncovered the cause of the accident, and after an investigation, the army extended the contract to the summer of 1909 when Orville could fly again.[95]

First Military Flyer, 1909

In May 1909, the Wrights worked on their new military flyer at their old bike shop and the barn behind their brother Lorin's house at 1243 West Second Street.[96] Powered by a four-cylinder Wright 30.6-horsepower engine, the 740-pound plane had a wingspan of 36.5 feet, stood 7.9 feet high, and was almost 29 feet long. Once the Wright 1909 Military Flyer was completed, the Wrights went to Fort Myer and the military trials. Orville first flew there on June 29. However, he immediately flew into a tree, damaging the plane. Problem-free flights resumed on July 12 and Orville now began setting records, flying beyond the army's requirements. On July 27, with Lt. Frank Lahm on board, Orville flew for one hour and twelve minutes, setting a new duration record and surpassing the army's requirement of remaining airborne for one hour with a passenger. On his July 30 speed trial, he flew at 42.583 miles per hour, setting another new record and exceeding the army's 40-miles-per-hour requirement, earning the brothers a $5,000 bonus. On August 2, 1909, the U.S. Army expended $30,000 for the world's first military airplane, the Signal Corps Airplane No. 1.[97]



Army Lt. Frank P. Lahm and Glenn Curtiss watch Orville Wright fly the first military flyer at Fort Myer, Virginia, in 1909. Source: Library of Congress, Prints and Photographs Division [LC-USZ62-107091]

[95] Rumerman, "Things are Looking Up"; Crouch, *Bishop's Boys*, 374-75; Warnock, "Wright Brothers," 155.
[96] Ann Honious, *What Dreams We Have: The Wright Brothers and Their Hometown of Dayton, Ohio* (Fort Washington, PA: Eastern National, 2003), chap. 9, http://www.cr.nps.gov/history/online_books/daav/index.htm (accessed March 9, 2005).
[97] U.S. Centennial of Flight Commission, "First Military Flyer."

PART TWO: THE EARLY YEARS & WORLD WAR I, 1909-1918

Image of a "flying boat," produced by aviation pioneer Glenn Curtiss, on Lake Keuka, New York State, between ca. 1910 and ca. 1915. Source: Library of Congress, Prints & Photographs Division [LC-B2-2568-3]

3. AN INDUSTRY EMERGES[1]

Making Airplanes

The founding date of the American aircraft industry is often considered to be the Wrights' delivery of the Signal Corps Airplane No. 1 to the army, along with their promise to deliver more planes.[2] Opening the first airplane factory required capital for the construction of workshops, purchase of materials, and cash to pay wages to new workers. Similarly, turning out substantial numbers of aircraft required a cadre of workers trained for fabricating aircraft parts and assembling them on schedule. Finally, assembled planes needed appropriate marketing, and prickly issues about licensing the construction of Wright designs overseas needed to be resolved.

Wright Company Factory, Dayton, Ohio. Source: Library of Congress Prints & Photographs Division [LC-DIG-ppprs-00687]

For capital, the Wright brothers accepted the proposal of several well-connected New York investors, such as Cornelius Vanderbilt, and together they founded the Wright Company in November 1909. Construction on the Wright Company [NPS, 2009] factory on Home Avenue in Dayton began on January 10, 1910, and the plant was occupied in November 1910, becoming the first constructed for airplane manufacture. Aircraft assembly had actually started earlier in February 1910, in space leased from the Speedwell Motor Car Company plant on Wisconsin Boulevard. Engine production took place at 1127 West Third Street. When the company moved into its new factory, it had a production capability greater than any other American airplane manufacturing facility at the time. Eventually the facility produced thirteen distinct aircraft types, nine of which Orville tested.[3]

Initially, the Wrights planned to build two aircraft per month, but this plan proved overly optimistic. Design changes, patent disputes, and stiff competition from European builders hampered sales and licensed production in Europe, while at home the Wrights discovered that military contracts alone did not generate a strong or consistent source of revenue. By 1915, the Wright Company had delivered only 14 planes to the U.S. Army. Sales to the non-military market still encountered stiff competition and the pressing issue of patent disputes further

[1] This section is primarily taken from Roger Bilstein, "The Aviation Manufacturing Industry, 1904-1970s," prepared for the *American Aviation Heritage* theme study (Washington, DC: National Park Service, draft 2008).
[2] Donald M. Pattillo, *Pushing the Envelope: The American Aircraft Industry* (Ann Arbor: University of Michigan Press, 1998), 6.
[3] Judy Rumerman, "Later Wright Activities," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Wright_Bros/Later_Years/WR13.htm (accessed November 17, 2004); Tom D. Crouch, *The Bishop's Boys: A Life of Wilbur and Orville Wright* (New York: W. W. Norton, 1990), 412, 424, 435; Ann Honious, *What Dreams We Have: The Wright Brothers and Their Hometown of Dayton, Ohio* (Fort Washington, PA: Eastern National, 2003), http://www.nps.gov/history/online_books/daav/index.htm, chap. 9; National Park Service and Dayton Aviation Heritage National Historical Park, "The Wright Company Factory Boundary Assessment and Environmental Assessment" (Dayton, OH, January 2006), 7. The board of directors operated from the Night and Day Bank Building at 527 Fifth Avenue, New York. Crouch, *Bishop's Boys,* 411.

complicated the Wrights' position. About the only regular source of income for the Wrights and other early builders came from air shows, popularized by sensationalized advertising of aerial daredevils who would perform thrilling stunts for curious crowds. The frail planes and flamboyant pilots often generated lurid headlines because of dramatic crashes and fatalities, but none of this publicity contributed to the reputation of airplanes or aviation as a promising technology.

In 1913, the Wrights' company had the good fortune to hire Grover Loening, one of the first aviation designers who actually possessed an engineering degree. Loening completed his first degree at Columbia in 1908, and then earned a master's degree in 1910. One year later, the Queen Aeroplane Company, the leading producer and distributor in America of Blériot type planes, offered him a job. The Blériot had become a popular vehicle for many aspiring aviators in the United States after Louis Blériot flew across the English Channel in 1909. But after two years at the Queen organization Loening became general manager at the Wright Company. He became frustrated by the lack of direction and haphazard business practices at the Dayton factory and departed the next year. He then took a new position with a recently formed aviation squadron of the U.S. Signal Corps in San Diego, California. There he designed engineering improvements for the fickle training planes acquired by the Corps. He also wrote a series of pamphlets on airplane design and construction for use by local training officers. These eventually evolved into a textbook about building aircraft called *Military Aeroplanes*—one of the earliest publications of its type. Later, Loening organized his own aircraft firm on the East Coast and built a number of successful biplane amphibians (which alight on both land and sea) before selling the company in 1930.[4]

Glenn Curtiss also continued to be a serious competitor to the Wrights in the prewar years and Curtiss Aeroplane and Motor Company designs rapidly became major contenders in the international aerial exhibition circuit. These planes customarily used Curtiss's own lightweight, but powerful engines. With his background in competitive racing, Curtiss had a knack for showmanship and publicity that the Wrights lacked and his experience in building and selling motors gave him insights into production, promotion, and distribution that evaded the Wright brothers. As Curtiss sold more airplanes, he also spent more time working to improve their performance, making the Curtiss Aeroplane and Motor Company a stiff competitor to the staid Wright Company.

Glenn Martin was another prewar pioneer. Born and raised in the Midwest, he moved to California in 1905 and established an auto-repair shop. His acquaintance with other mechanically inclined individuals led him to the nascent sport of flying, and he built his first biplane in a rented church. He made a name for himself in West Coast air shows and long-distance flights, and produced a handful of military trainers. After America's entry into the war, he set up shop in Cleveland in 1917 as the Glenn L. Martin Company with a staff of bright young engineers that included Donald Douglas, who helped Martin produce the large twin-engine biplane MB-1 (Martin bomber No. 1), an important design of the era. Martin finally settled on the East Coast (1928) near Baltimore, in a location that supplied a large number of skilled workers plus nearby bodies of water that enables year-round testing of flying boats.[5]

[4] Roger E. Bilstein, *The Enterprise of Flight: The American Aviation and Aerospace Industry* (Washington, DC: Smithsonian Institution Press, 2001), 12-13, 25; Grover Loening, *Our Wings Grow Faster* (New York: Doubleday, 1935), 21-30, 48-55, 61-62.

[5] Roger E. Bilstein, "Flying High: The Aviation Manufacturing Industry in the United States," (2005) essay submitted to the National Park Service for draft *American Aviation Heritage* National Historic Landmarks Theme

Airshows & Exhibition Flying

Governors Island, 1909-1910

The summer of 1909 was an eventful one for both Curtiss and the Wrights. Their new popularity gained them an invitation to fly exhibition flights in America and Europe. In the fall of 1909, New York planned to celebrate the anniversary of both Robert Fulton's steamboat voyage on the North River and Henry Hudson's entry into New York Harbor. As part of the festivities, the Hudson-Fulton Commission approached both Curtiss and Wilbur to fly exhibition flights anytime between September 25 and October 9. Wilbur negotiated an award of $15,000 to fly over 10 miles or one hour, and Curtiss settled on an award of $5,000 to fly from Governors Island [NHL, 1985; National Monument, 2003] to Grant's Tomb. The island was then headquarters for the U.S. First Army. Two "aeroplane sheds" were erected on the flight area consisting of "a sandy plain of 96 acres" that was "being enlarged with silt and muck dredged from the channel."[6]

The media hyped the event which pitted two planes embroiled in the patent fight. Wright and Curtiss, proclaimed the New York *Herald*, "will be chasing each other up the rivers and over the housetops."[7] It was Wilbur's public debut as a pilot in the United States as well as the first over-water flight in the country. In a test flight, Wilbur outfitted his plane with a canoe between the skids. He met his contract requirement when he flew from the island and circled the Statue of Liberty. On the other hand, Curtiss never made his flight to Grant's Tomb because winds and another contract obligation cut short his time on the island. In a bit of one-upmanship, and before over one million spectators, Wilbur combined his long flight with Curtiss's proposed flight, and on October 4, he flew a 33.5-minute, 20-mile, round-trip flight from Governors Island to Grant's Tomb.[8]

Curtiss later redeemed himself on May 29, 1910. He won a $10,000 prize awarded by the *New York World* for flying between two major cities, Albany and New York City, with the southern terminus at Governors Island. In addition, the Aero Club of America awarded Curtiss with the *Scientific American* Trophy for the third time, giving him permanent possession. The flight, states aviation historian Tom Crouch, "electrified the public. The *New York Times* devoted over four pages to the story, which was front-page news in every other paper in town." C. R. Roseberry, Curtiss's biographer, declared "the event…marked the birth of practical aviation in America," and that Curtiss's flight between two major cities had made aviation more than a sport or recreation.[9]

Study, 9.

[6] Crouch, *Bishop's Boys,* 406-08; C. R. Roseberry, *Glenn Curtiss: Pioneer of Flight* (New York: Syracuse University Press, 1991), 209 for island description.

[7] Roseberry, *Glenn Curtiss,* 210; Roseberry describes how at least 1,595 vessels were in the harbor for the event, 215.

[8] Roseberry, *Glenn Curtiss,* 214-18, 220-22; Crouch, *Bishop's Boys,* 407-08. Due to a prior commitment, Curtiss's contract ran for one week. Wilbur's contract ran for two weeks. Curtiss was also without his trophy-winning eight-cylinder *Reims Racer* that was on display in the New York Wanamaker department store. Instead he was using a new four-cylinder plane in the event. Roseberry, *Glenn Curtiss,* 210.

[9] Crouch, *Bishop's Boys,* 425; Roseberry, *Glenn Curtiss,* 280.

Airshows of the 1910s

During the prolonged Curtiss-Wright patent suit the sport of exhibition flying exploded onto the scene as American experimenters searched for ways to beat the patent.[10] Exhibition teams competed in air shows on transformed racetracks, golf courses, public parks, or other convenient open spaces. These air shows first exposed the American public to airplanes. Altitude, speed, and endurance competitions invoked a sense of "airmindedness," a term that meant "having enthusiasm for airplanes, believing in their potential to better human life, and supporting aviation development." Spectators suddenly became aware of both the airplane's entertainment value and utilitarian potential. In 1910, three major air shows in Los Angeles, Boston, and New York profoundly affected the future of American aviation, set aviation records, and marked the beginning of the earliest era of exhibition flying in the United States.[11]

Poster promoting America's first air meet. Source: Department of Archives and Special Collections, California State University

Following the world's first international air meet held in Reims, France, in 1909, aerial enthusiasts such as Glenn Curtiss and balloon and airship pilot Roy Knabenshue, the first person to pilot a dirigible successfully [Aeronautic Concourse of the 1904 Louisiana Purchase Exposition, NHL, 1987], promoted the first international air meet in the United States. The meet took place from January 10 to 20, 1910, south of Los Angeles, California, at Dominguez Field, on land known as Rancho San Pedro [Dominguez Ranch Adobe, NR, 1976]. The *Los Angeles Times* called the meet "one of the greatest public events in the history of the West." During the meet, Curtiss set a new air-speed record of approximately 55 miles per hour.[12]

The next air show, the Harvard-Boston Aero Meet, took place from September 3 to 13, 1910, at the newly christened Harvard Aviation Field in Atlantic (now Squantum), Massachusetts. This show was organized by the Harvard Aeronautical Society, a group formed in 1909 by Harvard scientists, alumni, and students to "promote the advance of aerial navigation [and] to contribute

[10] Walter J. Boyne, *The Smithsonian Book of Flight* (Washington, DC: Smithsonian Books, 1987), 62.
[11] Joseph J. Corn, *The Winged Gospel: America's Romance with Aviation* (Baltimore: Johns Hopkins University Press, 2002), 12, for "air minded" definition; David H. Onkst, "The First U.S. Airshows—the Air Meets of 1910," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Explorers_Record_Setters_Daredevils/early_US_shows/EX4.htm (accessed October 27, 2004). A very small number of the American public first gained exposure to airplanes when the Wright brothers flew the new *Wright Flyer III* at Huffman Prairie Flying Field in Dayton, Ohio, in 1905. Dayton Aviation Heritage National Historical Park communication to National Historical Landmarks Program, July 19, 2006.
[12] California State University Dominguez Hills, "The 1910 Los Angeles International Air Meet," http://www.csudh.edu/1910airmeet/guide.htm (accessed January 23, 2008); for *Los Angeles Times* quote, Peter Bergen, "Our Nation's First Air Meet," Aerofiles, http://www.aerofiles.com/dominguez.html (accessed October 27, 2004); Onkst, "The First U.S. Airshows."

both in theory and practice to the conquest of the air."[13] Here, aviators competed for the best speed, altitude, duration, distance, slow lap, getaway, and "dropping bombs on battle ship."[14]

The last major show of 1910 was the Belmont Park International Aviation Tournament at the Belmont Park Race Track held in New York from October 22 to 31. More than two dozen of the world's best aviators from England, France, and the United States competed for approximately $75,000 in prize money for the best speed, distance, altitude, and most precise landing. An altitude duel between two American pilots set a new soaring record of 9,714 feet.[15]

Exhibition Flying's First Era

Exhibition team members advanced aviation both technologically and socially in "an era of heroic flights."[16] Called birdmen and birdwomen, aviators of this early era of exhibition flying were among the first formally trained pilots in the United States. They learned their craft at flying schools such as those started by the Wright brothers and Glenn Curtiss. The Wrights and Curtiss also formed their own exhibition teams. Although the Wrights were not eager to enter the "montebank business," as they referred to stunt flying and exhibitions, the supplemental income was important to the survival of their manufacturing business.

The Wrights hired Knabenshue to manage their flying team. Knabenshue trained the first five team members at a flying school set up in March 1910 by Orville and the Wrights' longtime mechanic, Charlie Taylor. The school was located in Montgomery, Alabama, the later home of Maxwell Air Force Base. Curtiss trained his team, the Curtiss Exhibition Company, first from his facilities in Hammondsport, and later in San Diego. He pledged "to take on the Wright Fliers at every opportunity."[17]

Among stunt flyers, Lincoln Beachey became America's most famous and most skilled flyer during the pre-World War I era. Originally interested in bicycles and motorcycles, and then balloons, Beachey took lessons at the Curtiss Flying School in San Diego, California [Naval Air Station, San Diego, Historic District, NR, 1991]. After several crashes in Curtiss's airplanes, Beachey, nicknamed the "Flying Fool," became the largest moneymaker on the Curtiss Exhibition Team. During just one 31-week period in the 1910s, he entertained more than 17 million spectators. In his signature stunt, he would make a vertical climb until the engine stalled, dive toward the ground, and pull up at the last minute. He was the first to master the usually fatal spin, flying upside down, and the "loop-the-loop" maneuver. In 1911, he set an altitude record of 11,642 feet. Beachey's career in stunt flying came to a tragic end on March 14, 1915,

[13] John Lenger, "Conquest of the Air," *Harvard Magazine*, May-June 2003, http://www.harvardmagazine.com/on-line/050332.html (accessed November 9, 2007).
[14] Smithsonian Institution Research Information System (SIRIS), "Harvard Boston Aero Meet Photographs, 1910," http://siris-archives.si.edu/ipac20/ipac.jsp?uri=full=3100001~227870!0 (accessed November 9, 2007).
[15] Onkst, "First U.S. Airshows"; Joshua Stoff, *The Aerospace Heritage of Long Island* (Interlaken, NY: Heart of the Lakes Publishing, 1989), 18.
[16] Tom D. Crouch, *Wings: A History of Aviation from Kites to the Space Age* (New York: W. W. Norton, 2003), 143.
[17] Roseberry, *Glenn Curtiss,* 186; quote, Crouch, *Bishop's Boys,* 248; Rumerman, "Later Wright Activities." The Wright exhibition team first performed at Indianapolis Motor Speedway in June 1910 where crowds watched the Wright and Curtiss teams compete. In October 1910, both teams, with four aviators each, met at America's first international competition at Belmont Park racetrack in New York. Other independent American entries and European competitors also competed there for prizes totaling $72,300. The Wrights dissolved the exhibition team in November 1911 after several pilots died and profits declined. Crouch, *Bishop's Boys*, 428, 431-32, 453; Rumerman, "Later Wright Activities."

at the San Francisco Panama-Pacific International Exposition when his airplane's wings broke away and he crashed into the bay.[18]

Pioneering aviatrix, Harriet Quimby, helped overturn stereotypes about women's abilities and social roles. Inspired by the 1910 Belmont Park International Aviation Tournament, Quimby became the first licensed woman pilot in the United States in 1911. A member of the Moisant International Aviators exhibition team (founded in 1910 by airplane racer John Moisant), she is recognized as one of the world's best women aviators. "There is no reason," Quimby stated, "why the aeroplane should not open up a fruitful occupation for women. I see no reason why they cannot realize handsome incomes by carrying passengers between adjacent towns, why they cannot derive incomes from parcel delivery, from taking photographs from above, or from conducting schools for flying. Any of these things it is now possible to do."[19]

On April 16, 1912, Quimby became the first woman to fly across the English Channel. After crossing the Channel, Quimby resumed exhibition flying, but her career ended in tragedy only 11 months after she had learned to fly. On July 1, 1912, while flying with the event's organizer in the Third Annual Boston Aviation Meet in Squantum, Massachusetts, her brand new Blériot monoplane unexpectedly pitched forward and both passengers plunged to their deaths. In reflection, Aviatrix Amelia Earhart praised Quimby's achievement of crossing the Channel in 1912, stating that the flight "required more bravery and skill than to cross the Atlantic today…we must remember that, in thinking of America's first great woman flier's accomplishment."[20]

[18] U.S. Centennial of Flight Commission, "Lincoln Beachey," http://www.centennialofflight.gov/essay/Dictionary/BEACHEY/DI191.htm (accessed October 27, 2004); David H. Onkst, "Air Shows—An International Phenomenon," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Social/airshows/SH20.htm (accessed October 27, 2004).
[19] David H. Onkst, "Harriet Quimby," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Explorers_Record_Setters_and_Daredevils/quimby/Ex5.htm (accessed October 27, 2004).
[20] Ibid.

4. TRAINING THE MILITARY, 1909-1914

After the U.S. Army purchased the world's first military flyer on August 2, 1909, from the Wright brothers, the Army turned its attention toward training pilots, a requirement of the purchase contract with Wilbur. Because of its suitability for in-flight instruction, College Park, Maryland, [College Park Airport, NR, 1977] became the site of the army's training center. From here, Wilbur gave flying lessons to two officers: Lt. Lahm, who had encouraged the army to acquire an aircraft after meeting the Wrights in France, and Lt. Fredrick E. Humphreys. On October 8, Humphreys became the army's first "pilot" after flying for two minutes. Lahm later flew for seven minutes. Although it was not part of his contract, Wilbur also agreed to train Lt. Benjamin Foulois. Foulois began his lessons on October 23, but was only partially trained before he was ordered to Fort Sam Houston, Texas, with his enlisted "Combat Air Force" for better winter flying conditions. Foulois then became the first correspondence-trained pilot after the army ordered him to take the airplane and teach himself to fly. During his instruction with Wilbur at College Park he had never soloed, taken off, or landed. Following mailed instructions from the Wrights, Foulois began flying on March 2, 1910, and, by September, he had completed 62 flights. By early 1911, Foulois retired the flyer which he had wrecked and rebuilt several times.[1]

Beginning in 1910, the Wrights also set up what was arguably the world's first airport, a flight school at Huffman Prairie Flying Field [NHL, 1991]. "For $250 the school provided 10 days of training, including 'four hours of actual practice in the air and such instruction in the principles of flying machines as is necessary to prepare the pupil to become a competent and expert operator'." According to Crouch, "Huffman remained a world center of aeronautical achievement…and a teaching center." Orville later listed 115 people who learned to fly at the field, including a number of pioneering military aviators such as Henry H. "Hap" Arnold, a five-star general and leader in military aviation.[2]

Glenn Curtiss also trained pilots. In late 1910, after experimenting with the navy on flying planes from vessels for scouting duty, he offered free flight instructions to both army and navy officers at a winter camp he opened at San Diego Bay in 1911. Flight instruction also took place at his flying school in Hammondsport in 1912. Roseberry describes the Curtiss Aviation School as "the first open flying school" in the country. Flights from Kingsley Field, east of Hammondsport (later the site of Hammondsport High School), averaged 100 a day.[3]

Because the Army Signal Corps' funding requests of $200,000 to expand its aviation activities went unfulfilled, money for flying originally came from a general fund intended for maintenance of military telephone and telegraph installations.[4] On March 3, 1911, however, Congress finally

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[1] U.S. Centennial of Flight, "First Military Flyer," http://www.centennialofflight.gov/essay/Wright_Bros/Military_Flyer/WR11.htm (accessed April 7, 2005); Tom D. Crouch, *The Bishop's Boys: A Life of Wilbur and Orville Wright* (New York: W. W. Norton, 1990), 408; A. Timothy Warnock, "The Wright Brothers and the U.S. Army Signal Corps, 1905-1915," in *Reconsidering a Century of Flight,* ed. Roger D. Launius and Janet R. Daly Bednarek (Chapel Hill: University of North Carolina Press, 2003), 156-57.

[2] Wright-Patterson Air Force Base, "Huffman Prairie Flying Field," http://www.ascho.wpafb.af.mil/HUFFMAN.HTM (accessed April 7, 2005); Crouch, *Bishop's Boys,* 435-36.

[3] C. R. Roseberry, *Glenn Curtiss: Pioneer of Flight* (Syracuse: Syracuse University Press, 1991), 326. An image of the school is shown on plate no. 73.

[4] Juliette A. Hennessy, *The United States Army Air Arm, April 1861 to April 1917* (Washington, DC: Office of Air Force History, 1985), 40; Alfred Goldberg, ed., *A History of the United States Air Force* (New York: Arno Press, 1974), 4, commentary, 6. Neither pilot was injured in the College Park crash but the Signal Corps soon lost them to

appropriated its first funding designated specifically for military aviation in the amount of $125,000. Using these funds, the Signal Corps ordered five new airplanes: two Wright Model B's, two Curtiss Type IV Model D "Military," and a Wright Type B manufactured by W. S. Burgess, the first manufacturer licensed by the Wright Company.

In an effort to promote the sale of their airplanes to the military, many manufacturers provided the first formal pilot training. In April, three army officers trained with Curtiss on San Diego's North Island. Seventeen other service members soon joined them, training on the new planes. Among these pioneering flyers, Lieutenant G. E. M. Kelly became the first man to lose his life in an airplane training exercise when he crashed while attempting to land the Curtiss airplane at Fort Sam Houston on May 10, 1911. Following the accident, the fort's commanding general prohibited further flying at the fort.[5]

Funds were also provided for the newly reopened flying school at College Park where Wilbur Wright had instructed Lahm, Foulois, and Humphreys.[6] Between 1911 and 1912, the Army Signal Corps Aviation School operated from six hangars, a small headquarters building, and a tent that served as an emergency hospital.[7] During their first year at College Park, pilots made a 42-mile flight to Frederick, Maryland; conducted record-breaking altitude flights (3,260 and 4,167 feet respectively); and tested a bombsight invented by former army officer Riley E. Scott.[8]

Most strategists, however, continued to believe that the "the amount of damage [the airplane] will do by dropping explosives upon cities, forts, hostile camps, or bodies of troops in the field, to say nothing of battleships at sea, will be so limited as to have no material effects on the issues of a campaign." The plane, these strategists insisted, was best suited to reconnaissance missions. Despite the persistence of this view, aviators explored other uses for airplanes. Curtiss was among the first to experiment independently with aerial bombardment. On June 30, 1910, he made his first attempt with his *Golden Flyer* in Hammondsport. Two months later, on August 20, 1910, he made a second attempt at Sheepshead Bay racetrack near New York City. With Curtiss at the controls, Lt. James Fickel fired the first shot from an airplane using a U.S. Army Springfield rifle at an altitude of 100 feet.[9]

The first real bombing exercise occurred in 1911 when Lieutenant Myron Crissy hand-dropped live bombs from a Wright B during trials near San Francisco. In 1912, Lt. Thomas DeWitt Milling piloted a Wright B at College Park while his senior officer, Captain Charles de Forest

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their regular assignments. The army was then left without a usable plane or a fully qualified pilot.

[5] The amount of funding Congress approved was cut in half from its original proposal of $250,000. Albert F. Hurley and William C. Heimdahl, "The Roots of U.S. Military Aviation," in *Winged Shield, Winged Sword: A History of the United States Air Force,* ed. Bernard C. Nalty, (Washington, DC: Air Force History and Museums Program, 1997), 1:15, 18; Alan Gropman, "Aviation at the Start of the First World War," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Air_Power/Pre_WWI/AP1.htm (accessed January 1, 2005); reference to five new airplanes in College Park Aviation Museum, "Army Signal Corps Aviation School," http://www.pgparks.com/places/historic/cpam/3army.html (accessed April 29, 2005).

[6] Emma J. H. Dyson, Dean A. Herrin, and Amy E. Slaton, *The Engineering of Flight: Aeronautical Engineering Facilities of Area B, Wright-Patterson Air Force Base, Ohio* (Washington, DC: National Park Service, 1993), 2.

[7] College Park Aviation Museum, "Army Signal Corps Aviation School." The first flight trainees (2nd Lt. Henry H. "Hap" Arnold and 2nd Lt. Thomas DeWitt Milling) were initially sent to the Wright Company's flying school near Dayton, Ohio, for training before reporting for duty at College Park on June 15, 1911.

[8] Gropman, "Aviation at the Start of the First World War." Riley Scott's bombsight, a sighting device used for aiming bombs, showed promise but the War Department refused to purchase it. Scott entered a competition in Europe where he won a $5,000 prize for his invention.

[9] Ibid.

Chandler, became the first to fire a machine gun from an airplane.[10] The use of the Lewis low-recoil machine gun was so successful that aviators requested 10 more guns for additional experiments. But the request was denied both because the Lewis gun had not yet been adopted for army use and because airplanes were still used only for reconnaissance. The Lewis gun would eventually become standard armament on Allied planes during World War I.[11]

Events abroad, including an escalation of tensions between Mexico and the United States and the outbreak of war in Europe, prompted the army to expand its aviation capabilities. Better pilot training was the focus of this expansion. The Signal Corps accepted Curtiss's invitation to send officers to North Island in San Diego and the College Park school formally relocated to San Diego in November and December of 1912. The San Diego region's warmer temperatures, flat terrain, good beaches, and protected stretches of water provided a better setting for flying temperamental, and often, unreliable planes.

The San Diego flight school became the army's first permanent aviation school. Designated the Signal Corps Aviation School in 1913, the school emphasized ground training in addition to flight operations. Distinguished scientists, recruited from the Smithsonian Institution, Stanford University, and the U.S. Weather Bureau, instructed future aviators. At the school, pilots continued to experiment with the Riley Scott bombsight. They also explored the development of minefield detection, and the potential of parachutes while setting altitude and cross-country flight records.[12]

Naval Aviation

Although the navy had used balloons during the Civil War, the official birth of U.S. naval aviation is recognized as May 8, 1911, the day on which the navy ordered its first aircraft.[13] A year before this purchase, the navy had tasked Captain Washington I. Chambers, along with navy constructor William McEntee and Lieutenant N. H. Wright, to investigate aviation technology. Chambers, who ultimately took charge of naval aviation, asked the Wright Company to fly a plane from the deck of a cruiser.[14] When the Wright Company refused, he made the same offer to Eugene Ely, a flyer for Curtiss's exhibition company. On November 14, 1910, Ely became the first pilot to take off from a ship. He used an 83-foot-long ramp mounted on the bow of the

[10] Rebecca Hancock Cameron, *Training to Fly: Military Flight Training, 1907-1945* (Washington, DC: Air Force History and Museums Program, 1999), 33. Captain Charles de Forest Chandler was the first chief of the Aeronautical Division and in June 1911, he became the commandant of the College Park flying school. Hennessy, *United States Army Air Arm*, 61.

[11] Roger E. Bilstein, *Flight in America: From the Wrights to the Astronauts,* rev. ed. (Baltimore: Johns Hopkins University Press, 1994), 32; Goldberg, *A History of the United States Air Force*, 7.

[12] Goldberg, *History of the United States Air Force,* 8. By 1913, San Diego was not the army's only flight school. In addition to a small detachment at Texas City, Texas, two overseas training schools had been established: one in the Philippines and one in Hawaii. Frank Lahm, one of the army's first pilots, opened a flying school at Fort William McKinley near Manila in March 1912, and Lt. Harold Geiger, established a school at Fort Kamehameha in Hawaii in the summer of 1913, but difficulty maintaining seaplanes and treacherous winds in the area, forced the school to close a year later. Lahm trained a number of pilots in the two years the school in Manila was operating. Goldberg, 7. By August of 1913, the three air schools accounted for 16 pilots, 8 student pilots, and 17 airplanes in the air service with several more detailed to aviation duty by the end of the year. Hennessy, *United States Army Air Arm*, 94.

[13] Roy A. Grossnick, ed., *Kite Balloons to Airships…:The Navy's Lighter-than-Air Experience* (Washington, DC: Naval Historical Center, n.d.), 3.

[14] U.S. Department of the Navy, Naval Historical Office, "Chronology of Significant Events in Naval Aviation," www.history.navy.mil/branches/org4-5.htm, 3 (accessed June 21, 2005).

light cruiser USS *Birmingham* near Hampton Roads, Virginia, and flew 2.5 miles to Willoughby Spit.[15]

On January 18, 1911, Ely made a flight both to and from a cruiser. He took off from the old Presidio parade ground, near San Francisco and landed his Curtiss Model D biplane on a 119-foot flight deck built on the armored cruiser USS *Pennsylvania* in San Francisco Bay. The ship's captain heralded the event as "the most important landing of a bird since the dove returned to the ark."[16] Ropes with sandbags attached at each end stretched across the landing deck to become the first "arresting gear" installed on a ship. Placed at one-foot intervals, the rope was raised high enough off the deck to engage hooks affixed to the airplane to help bring it to a stop. After lunch with the captain, Ely took off amid the cheers of crewmen and returned to the city. Ely's flight ushered in a new age in military flight; "the Aircraft Carrier had been born."[17]

Although Ely's exploits generated tremendous interest in the United States, the navy still did not allocate funding to purchase airplanes. However, the navy did accept Curtiss's offer of free flight instruction in San Diego. Lieutenant Theodore Gordon "Spuds" Ellyson, a submarine officer, joined the three army officers who had already been ordered to San Diego [Rockwell Field, NR, 1991]: Lieutenants Paul W. Beck, G. E. M. Kelly, and John C. Walker, Jr. There, all four men trained on a Curtiss one-seater.[18]

The navy's new interest in aviation spurred Curtiss to experiment with hydroplanes, airplanes capable of lifting off water. On January 26, 1911, Curtiss flew a hydroplane from the surface of the San Diego Bay. Three weeks later Curtiss contacted the captain of the USS *Pennsylvania* with an offer to fly over and be hoisted aboard. In less than half an hour, Curtiss landed his plane next to the cruiser, was hoisted on board, lowered back to the water, and flew back to the beach hangar.[19] Because "an airplane on floats was something that seagoing people could understand," Curtiss's achievement spurred the navy to support the airplane.[20] In 1911, Congress finally appropriated $25,000 for naval aviation. With its new funding, the navy ordered three officers to "aeroplane factories" for lessons, and purchased three airplanes: one Wright and two Curtisses.[21] Lieutenants John Rodgers and John H. Towers joined Ellyson and became the navy's second and third aviators.[22] A short time later, the Navy Department also

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[15] Capt. W. H. Seitz, "A History of United States Naval Aviation," U.S. Department of the Navy, Bureau of Aeronautics (Washington, DC: Government Printing Office, 1930), www.history.navy.mil/download/sitz-nah.pdf (accessed May 10, 2005); U.S. Department of the Navy, "Eugene Ely's Flight from USS *Birmingham,* 14 November 1910," http://www.history.navy.mil/photos/events/ev-1910s/ev-1910/ely-birm.htm (accessed May 10, 2005); Tom D. Crouch, *Wings: A History of Aviation from Kites to the Space Age* (New York: W. W. Norton, 2003), 144.

[16] Bill Gunston, ed., *Aviation Year-by-Year* (London: Dorling Kindersley, 2001), 88; Roseberry, *Glenn Curtiss*, 321; quote, Crouch, *Wings,* 144.

[17] U.S. Department of the Navy, "Eugene B. Ely, (1886-1911)," http://www.history.navy.mil/photos/pers-us/uspers-e/eb-elay.htm (accessed May 10, 2005); Vern Renaud and Fred Wolff, "Hell Rider: The Glenn Curtiss Story," *Aviation Quarterly* 5, no. 1 (1979), 48, aircraft carrier quote, 49; Roseberry, *Glenn Curtiss,* 310.

[18] Roger D. Launius, "The Wright Brothers, Government Support for Aeronautical Research, and the Evolution of Flight," in *Reconsidering a Century of Flight,* ed. Roger D. Launius and Janet R. Daly Bednarek (Chapel Hill: University of North Carolina Press, 2003), 7; Roseberry, *Glenn Curtiss*, 296.

[19] Roseberry, *Glenn Curtiss,* 308-09, 314-15.

[20] S. Paul Johnston, *Flying Fleets: A Graphic History of U.S. Naval Aviation* (New York: Duell, Sloan and Pearce, 1941), ix.

[21] W. I. Chambers, "Report on Aviation," Annual Report of the Secretary of the Navy for 1912, app.1 (Washington, DC, 1912): 155-169, in "Development in the United States Navy," National Aeronautics and Space Administration, *SP-4103 Model Research,* vol. 2, app. H (1/4), http://www.history.nasa.gov/SP-4103/app-h1.htm (accessed April 29, 2005).

[22] Captain Albert L. Raither, "Naval Aviation: The Legacy," in Richard C. Knott, ed., *The Naval Aviation Guide,* 4th

ordered its first hydroplane from Curtiss. In July of 1911, Curtiss delivered the A-1 Triad, named for its ability to perform on land, sea, and in the air.[23]

Following the delivery of these planes, the navy set up camp at Greenbury Point, Annapolis, Maryland. There, they built a hangar "where a sufficient area of flat land was prepared for an aerodrome by the leveling of some trees and the partial filling of a swamp." The first night operations were conducted at this location.[24] In December 1911, the airplanes and pilots transferred to San Diego, California, where they pitched camp. At the end of winter they returned to Annapolis and camped "nearer the engineering experiment station on the North Shore of the Severn River" at Greenbury Point. It was here in May of 1912 that First Lieutenant A. A. Cunningham became the first marine assigned to aviation duty.[25]

The first Curtiss flying boat capable of carrying two passengers took off from San Diego Bay on January 10, 1912. Before the year was over, Curtiss had produced a refined version of the boat—the Curtiss F-Boat—which he sold to the navy, the army, and wealthy sportsmen pilots. On November 12, 1912, Ellyson successfully launched a Curtiss seaplane using a catapult. Designed at the Naval Gun Factory in Washington, D.C., the catapult was mounted on a float anchored in the Anacostia River opposite the Navy Yard [Washington Navy Yard, NHL, 1961]. The device was a forerunner of the catapult eventually used on aircraft carriers.[26]

Chambers now believed that hydroaviation was the wave of the future. A "water aerodrome is nearly always available, is safer in landing, is less obstructed, and the aerial currents over water are less treacherous than over land," he raved.[27] By 1912 Chambers was arguing that recent achievements in aeronautics had already "fully demonstrated that of two opposing forces, the one which possesses superiority in aerial equipment and skill will surely hold a very great advantage."[28]

Within a year, Captain Chambers arranged to have the aviation camp moved to Guantanamo Bay, Cuba, where the navy's five planes and aviators could conduct further tests with the fleet.[29] In January and February of 1913, the aviators performed scouting missions and practiced spotting mines and submerged submarines. During more than 100 training flights, the unit carried line officers on local hops to demonstrate the safety and maneuverability of the airplane, winning converts to the promise of aviation.[30]

In the following October, the Secretary of the Navy appointed a board to survey the service's aeronautical needs. As a result of the board's recommendations, an Office of Naval Aeronautics was established on July 1, 1914, and an aviation training station was established in Pensacola

ed. (Annapolis, MD: Naval Institute Press, 1985), 3.

[23] Edward Jablonski, *Sea Wings: The Romance of the Flying Boats* (New York: Doubleday, 1972), 7; Roseberry, *Glenn Curtiss,* 319.

[24] Raither, "Naval Aviation," 3.

[25] Ibid. Tents made for easy removal of a camp to a new place, were cheaper than permanent sheds, and provided the ability to move in short notice.

[26] Jablonski, *Sea Wings,* 7; Seitz, "A History of U.S. Naval Aviation," 6; Daniel L. Haulman, *One Hundred Years of Flight: USAF Chronology of Significant Air and Space Events, 1903-2002* (Maxwell Air Force Base, AL: Air University Press, 2003), 9.

[27] Chambers, "Report on Aviation" in "Instructions and Tests."

[28] Ibid., in "Introduction."

[29] Raither, "Naval Aviation," 3.

[30] Scot MacDonald, "Evolution of Aircraft Carriers: The Aeroplane Goes to Sea," *Naval Aviation News* (February 1962): 5, www.history.navy.mil/branches/car-toc.htm (accessed August 9, 2005).

[Pensacola Naval Air Station Historic District, NHL, 1976] on a sandy strip of Florida shoreline. Lieutenant Towers, who would soon lead a detachment to Tampico, Mexico, aboard the USS *Birmingham*, took over the aviation camp that would become "the cradle of naval aviation."[31]

In 1914, the navy also became interested in another Curtiss project. Wanamaker Department Stores heir, Rodman Wanamaker, had commissioned Curtiss to build a large flying boat. The *America* made its first test flight in June of 1914, at Lake Keuka in Hammondsport, New York. With a wingspan of 74 feet and powered by two engines, *America* was the largest airplane produced in the United States. The advent of World War I postponed a hoped-for transatlantic crossing and the *America* and her duplicate were shipped off to war for use not by the navy, but by the Royal Naval Air Service.[32]

Consequences of the Patent Battle

The Curtiss-Wright patent battles that had begun in 1909 ultimately took their toll on both parties as legal and court fees drained their financial resources. On May 30, 1912, after Wilbur died from typhoid fever, the family claimed that the stress of the patent litigation had weakened Wilbur, making him susceptible to the infectious disease. Finally, in 1913, a Federal Circuit Court of Appeals ruled in favor of Orville Wright. The decision "ordered Curtiss to cease making airplanes with two ailerons that operated simultaneously in opposite directions." But that was not the end to litigation. Curtiss received unexpected help from automobile magnate Henry Ford who had experienced a similar action relating to an automobile patent suit heard by the same judge. Ford's success in the case kept his business from being destroyed. Ford's attorney advised "Curtiss to bait Orville to reopen the litigation by devising a new configuration for lateral control using the Langley aerodrome that hung in the Smithsonian." If successful, the court could find that Curtiss's design was based on Langley's rather than the Wrights' plane. Although Ford's lawyer persuaded the court to stay the old verdict temporarily, the U.S. Circuit Court of Appeals upheld the original decision in the *Wright v. Curtiss* case on January 13, 1914.[33]

Assessing the impact of the Curtiss-Wright patent battle, Air Force historian A. Timothy Warnock has argued that "the Wright Company's patent litigation retarded not only the development of the Wright aircraft but of all U.S. airplanes."[34] Judy Rumerman agreed, arguing that "none of the later Wright aircraft measured up to contemporary European machines. Government investment by nations facing the prospect of war had moved the technology rapidly forward. The U.S. would not catch up to Europeans until the 1920s."[35]

Eventually Orville Wright and Glenn Curtiss ended their manufacturing careers. In 1915, Orville sold the Wright Company to a syndicate of New York financiers for $1.5 million plus a retainer for consultancy services. In June 1916, Orville moved from the old shop at 1127 West Third into a new brick laboratory he built at 15 North Broadway. He continued working at the laboratory for 30 years. He lived out the remainder of his life in Hawthorn Hill [NHL, 1991;

[31] Naval Air Station Pensacola, Florida, "The Cradle of Naval Aviation," http://naspensacola.navy.mil/history.htm (accessed June 29, 2005, since removed).
[32] Jablonski, *Sea Wings,* 9-10; Roseberry, *Glenn Curtiss,* 379.
[33] Boyne, *Smithsonian Book of Flight,* 62. Quotes, "Glenn Curtiss and the Wright Patent Battles."
[34] Warnock, "The Wright Brothers," 162.
[35] Judy Rumerman, "Later Wright Activities," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Wright_Bros/Later_Years/WR13.htm (accessed November 17, 2004).

NPS, 2009], a Georgian Revival mansion he had designed with Wilbur and built near Dayton.[36] Glenn Curtiss continued his career in aviation manufacturing aircraft until 1920 when the company underwent financial reorganization. He then settled in Miami Springs, Florida, [Glenn Curtiss House, NR, 2001] and became a real estate developer where he lived until his death in 1930.[37]

[36] Bilstein, *Enterprise of Flight*, 3-7; Grover Loening, *Take off into Greatness: How American Aviation Grew So Big So Fast* (New York: Putnam, 1968), 26-29.
[37] Crouch, *Bishop's Boys*, 448, 468, 512.

5. MILITARY AVIATION'S POTENTIAL, 1913-1917

Although the Curtiss-Wright court case was resolved, other patent wars between airplane producers continued to divide the aeronautical community. These patent wars "tended to discourage bold innovation" and "probably hindered the progress of U.S. aviation."[1] The impact of this upon American military aircraft design first became evident between 1913 and 1916, when tensions between Mexico and the United States escalated.

During the prewar years America had a mobile and lightly armed force rather than a modern heavily armed force capable of sustained combat and astute observers still questioned whether an aircraft could become an effective weapon of war. In 1916, Henry Woodhouse, editor of *Flying* magazine, predicted that the plane would not add barbaric new terrors to warfare. Orville Wright also saw a benign future for aviation, predicting business trips, air cargo, and an airmail service. But following the American declaration of hostilities, Wright endorsed bombing German munitions production sites and advocated air supremacy to keep enemy air reconnaissance suppressed.[2]

The 1st Aero Squadron

After General Victoriano Huerta seized power in Mexico at the end of February 1913, relations between the U.S. and Mexico deteriorated, providing the military with its first opportunity to organize and test its fledgling air service. The Signal Corps sent eight pilots and nine airplanes to Texas City, Texas. Capt. Charles Chandler, who had earlier directed the instruction of enlisted men in ballooning and served as commander of the aviation school at College Park, Maryland, organized a provisional unit—the 1st Aero Squadron—to carry out military operations in the field. This became "the first air service operating unit of any kind ever organized in compliance with War Department regulations" and until 1917, the Squadron was America's only operational air unit.[3] Although pilots never faced combat during this event, their time spent training in the air made them realize they were operating obsolete aircraft.[4]

In April 1914, a second confrontation with Mexico sent airmen back to Texas. The Mexican government had arrested several sailors from the USS *Dolphin* for entering a prohibited area. Amid outraged demands by the United States for an apology from the Mexican government, a German warship arrived with guns and supplies for the Mexicans and the "Tampico Incident" brought the two North American neighbors to the brink of war. Although army pilots had returned to Texas, naval aviators became the first American flyers to see combat overseas. When President Woodrow Wilson authorized military action against Mexico at Vera Cruz, five Curtiss flying boats were hastily assembled aboard the USS *Mississippi* and the USS

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[1] Roger E. Bilstein, *The Enterprise of Flight: the American Aviation and Aerospace Industry* (Washington, DC: Smithsonian Institution Press, 2001), 16.
[2] Roger E. Bilstein, *Flight in America: From the Wrights to the Astronauts,* rev. ed. (Baltimore: Johns Hopkins University Press, 1994), 38-39.
[3] Quote in Juliette A. Hennessy, *The United States Army Air Arm, April 1861 to April 1917* (Washington, DC: Office of Air Force History, 1985), 120; HistoryNet.com, "Mexican Expedition: 1st Aero Squadron in Pursuit of Pancho Villa," http://www.historynet.com/mexican-expedition-1st-aero-squadron-in-pursuit-of-pancho-villa.htm (accessed September 7, 2005). The squadron had only provisional status until December of 1913.
[4] Alfred Goldberg, ed., *A History of the United States Air Force* (New York: Arno Press, 1974), 7; Albert F. Hurley and William C. Heimdahl, "The Roots of U.S. Military Aviation," in *Winged Shield, Winged Sword: A History of the United States Air Force,* Bernard C. Nalty, ed., (Washington, DC: Air Force History and Museums Program, 1997), 1:9, 20, 28-29.

Birmingham. After being lowered into the Gulf of Mexico for takeoff, the planes searched for mines in the Vera Cruz harbor and flew periodic reconnaissance flights over the mainland.[5] When crew members found a few bullet holes in the fabric of one plane, "news-hungry correspondents on the scene gleefully filed lurid news copy about the first U.S. airplanes to be fired on in anger."[6] The crisis abated with the ABC (Argentina, Brazil, and Chile) Mediation Conference held in May of 1914 in Niagara Falls, Canada, and the withdrawal of U.S. naval forces from Mexico.[7]

The army's success in forming the 1st Aero Squadron and conducting flight training convinced Congress to create the Aviation Section within the Signal Corps on July 18, 1914. More than one million dollars was appropriated for military aeronautics between 1914 and 1915.[8] This legislation gave statutory recognition to army aviation, "putting it on a firm and permanent basis" with the "duty of operating or supervising the operations of all military aircraft, including balloons and aeroplanes, all appliances pertinent to said craft, and signaling apparatus of any kind when installed on said craft. The legislation authorized 60 officers and 260 enlisted men (in addition to personnel already on aviation duty with the Signal Corps) and charged the army with training officers and enlisted men in matters pertaining to military aviation."[9]

In September of 1914, the army's fledgling 1st Aero Squadron returned to San Diego. Eighteen months later, the squadron, now commanded by Capt. Benjamin Foulois, accompanied Brig. Gen. John J. Pershing in an unsuccessful and punitive 11-month pursuit of Mexican revolutionary, Gen. Francisco "Pancho" Villa. During the chaos of the Mexican Revolution, forces loyal to Villa had crossed the border on March 9, 1916, and killed 18 U.S. citizens (8 soldiers and 10 civilians) in the sleepy border town of Columbus, New Mexico [Village of Columbus and Camp Furlong, NHL, 1975]. Without consulting the Mexican government, President Woodrow Wilson ordered General Pershing to organize a force of 15,000 troops and pursue Villa into Mexico and take him "dead or alive." With 10 pilots, 84 enlisted men, and 8 planes, the squadron ordered to fly aerial reconnaissance in support of cavalry patrols arrived on March 15.[10] The pilots flew JN-3 Jenny aircraft, a biplane Glenn Curtiss had designed as a trainer for the army.

By April 20, the remnants of the 1st Aero Squadron returned to Columbus, New Mexico. Of the eight JN-3 Jenny aircraft, five had been wrecked and one abandoned in hostile territory.[11] Contaminated fuel, combined with the dry climate that caused the airplanes' laminated wood propellers to crack, and inadequate organization, "clearly underscored the lack of experience and preparedness of American military aviation."[12] The aircraft also lacked sufficient power to cross

[5] Pamela Feltus, "United States Participation in World War I," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Air_Power/U.S._in_WWI/AP8.htm (accessed January 7, 2005). The aircraft dispatched included Curtiss C-3, C-4, C-5 flying boats, and A-3 and A-4 Curtiss pushers.
[6] Bilstein, *Flight in America,* 33.
[7] "Great American History Fact-Finder-Tampico Incident," http://college.hmco.com/history/readerscomp/gahff/html/ff__175700_tampicoincid.htm (accessed September 7, 2005).
[8] Stephen L. McFarland, *A Concise History of the U.S. Air Force*, Air Force History and Museums Program (Washington, DC: U.S. Government Printing Office, 1997), 3; Emma J. H. Dyson, Dean A. Herrin, and Amy E. Slaton, *The Engineering of Flight: Aeronautical Engineering Facilities of Area B, Wright-Patterson Air Force Base, Ohio* (Washington, DC: National Park Service, 1993), 3. The new section had a "paper" strength of 6 airplanes, 60 officers, and 260 enlisted personnel.
[9] Goldberg, *History of the United States Air Force,* 8.
[10] Ibid., 9, 10; Hurley and Heimdahl, "Roots of U.S. Military Aviation," 30.
[11] Hennessy, *United States Army Air Arm,* 168-72.
[12] Bilstein, *Flight in America,* 33.

the Sierra Madres and encountered difficulties in navigating drafty mountain passes. The army's experience in Mexico proved to be an invaluable training exercise, highlighting problems that would have gone unnoticed before World War I. In response to mounting criticism, the Signal Corps created a Technical Advisory and Inspection Board "to recommend equipment, inspect factories, and evaluate aircraft."[13]

What military strategists failed to see, writers such as H. G. Wells had already envisioned; in his 1908 novel *The War in the Air,* Wells had described a fictional account of German bombers attacking New York City, raining terror from the skies.[14] Aviation pioneer and manufacturer Glenn Martin was one of the rare few who identified airplanes as the devastating weapons of war they would prove to be. Just three days after German troops rolled into Belgium, Martin wrote about the potential importance of airpower in combat in an August 7, 1914, *Los Angeles Evening Herald* article. "The aeroplane will practically decide the war in Europe," Martin boldly declared. Predicting that "veritable flying death will smash armies, wreck mammoth battleships and bring the whole world to a vivid realization of the awful possibilities of a few men and a few swift winging aerial demons," Martin asserted that "the old time war tactics are no more."[15]

World War I in Europe, 1914-1917

By World War I, every major nation—with the exception of the United States—had devoted significant resources to developing aerial components in their military arsenals. In August 1914, Germany had assembled approximately 230 airplanes and 4 dirigibles; Great Britain, 110 airplanes; and, France, 130 airplanes. By comparison, the U.S. had produced only 15 military and 34 civil aircraft.[16]

Early wood and fabric military planes were divided between monoplanes and biplanes. These had a top speed of 60 or 70 miles per hour, a stall speed of 50 to 60 miles per hour, an endurance of an hour or two, and the capability to carry a pilot and an observer but little or no armament. Described as "fragile, cranky, unreliable, difficult to fly, and subject to structural failure if pressed too hard," these warplanes had significant problems. Yet despite these limitations, early military airplanes and their more sophisticated descendants participated in virtually every type of modern aerial combat within the first six months of the war.[17]

At first, European unarmed, open-cockpit, military aircraft provided primarily reconnaissance and artillery observation. With this relative safety, opposing military pilots often waved to one another as they passed en route to their battle stations. This cordiality ceased as warfare intensified and nations sent single-seat 'scouts' into the air over their own military operations to fend off the intruding enemy with pistol and rifle fire.[18] Eventually "fast, highly maneuverable aircraft were dogfighting, while other specialized types carried out bombardment and reconnaissance. Not only did the foreign machines outfly the slow Curtiss types that Foulois and

[13] Hurley and Heimdahl, "Roots of U.S. Military Aviation," 31.
[14] Ron Dick and Dan Patterson, *Aviation Century: The Early Years* (Ontario, Canada: Boston Mills Press, 2003), 57.
[15] Wayne Biddle, *Barons of the Sky: From Early Flight to Strategic Warfare: The Story of the American Aerospace Industry* (New York: Simon & Shuster, 1991), 65-66.
[16] Bilstein, *Flight in America,* 31; Donald M. Pattillo, *Pushing the Envelope: The American Aircraft Industry* (Ann Arbor: University of Michigan Press, 1998), 32.
[17] Walter J. Boyne, *Chronicle of Flight: A Year-by-Year History of Aviation* (Lincolnwood, IL: Publications International, 2003), 48.
[18] Bilstein, *Flight in America,* 31-32.

his squadron had used in Mexico, European pursuit planes mounted machineguns synchronized to fire through the propeller's arc, a far cry from the few hand-held Lewis guns tested by the airmen in Pershing's expedition."[19] Now, in addition to enduring the numbing cold, pilots faced combat fatigue and the specter of death in a flaming dive.

American aircraft production lagged until the country entered World War I. Facing the ongoing patent issue and desperately in need of aircraft, an advisory panel led by Assistant Secretary of the Navy Franklin D. Roosevelt recommended the formation of a patent pool. Overseeing the pool was the first formal organization of aircraft manufacturers, the Aircraft Manufacturer's Association. The association facilitated the cross-licensing of patents for the duration of the war.

Military Ballooning

Along with heavier-than-air craft, the military also pursued the use of balloons and dirigibles prior to World War I. The navy, in particular, advocated the development of a lighter-than-air (LTA) program. Its Director of Naval Aviation believed the dirigible, when combined with other air and surface craft, would provide the best protection against submarines.[20] On August 22, 1908, Thomas Baldwin sold the U.S. Army Signal Corps an improved dirigible powered by a 20-horsepower Curtiss engine for $10,000. Designated the SC-1 (Signal Corps No. 1), this dirigible was the first powered aircraft owned by the U.S. military.

On June 1, 1915, the Connecticut Aircraft Company won a contract to design and construct the navy's first dirigible. Assembled at the Hartford Armory in March 1916 and delivered to the navy on December 1916, the DN-1 (Dirigible, Non-Rigid, No. 1) did not see service beyond three flights. In April 1917, technical and mechanical flaws led to its dismantling. The DN-1 was the only one of its class ever built.[21]

Following this embarrassment with the DN-1, the Secretary of the Navy authorized the Aircraft Division of the Bureau of Construction and Repair to order the construction of 16 B-Class dirigibles on February 4, 1917. The Connecticut Aircraft Company, along with four other companies, including Goodrich and the Goodyear Tire and Rubber Company, were tasked with building the B-Class dirigibles. Used off the Atlantic coast, these aircraft conducted three types of patrol duties: standard patrol of an assigned area, emergency patrol in response to the sighting of a submarine or on search-and-rescue missions, and escort patrol of ships and convoys. These patrols successfully deterred German U-boats from attacking ships and convoys.[22]

The navy placed its first order for a free (untethered) balloon from the Goodyear Tire and Rubber Company [Goodyear Administration Building] in September 1915. An order for an experimental model of a kite or observation balloon for gunfire spotting and reconnaissance missions soon followed. In 1916, after testing the kite balloon in Pensacola, the navy ordered two more kite balloons from Goodyear. Tests on board the USS *North Carolina* and the USS *Nevada* reaffirmed the benefit of battleships using kite balloons for gunfire spotting, scouting,

[19] Hurley and Heimdahl, "Roots of U.S. Military Aviation," 33.
[20] Roy A. Grossnick, ed., *Kite Balloons to Airships…: The Navy's Lighter-than-Air Experience* (Washington, DC: Naval Historical Center, n.d.), 3; Tom D. Crouch, *The Eagle Aloft: Two Centuries of the Balloon in America* (Washington, DC: Smithsonian Institution Press, 1983), 528.
[21] Grossnick, *Kite Balloons to Airships,* 4-5; J. Gordon Vaeth, *Blimps & U-Boats: U.S. Navy Airships in the Battle of the Atlantic* (Annapolis, MD: Naval Institute Press, 1992), 2.
[22] Grossnick, *Kite Balloons to Airships,* 3-6, 12-13; Douglas H. Robinson and Charles L. Keller, *Up Ship!: A History of the U.S. Navy's Rigid Airships 1919-1935* (Annapolis, MD: Naval Institute Press, 1982), 8.

and reconnaissance missions. Further testing aboard the USS *Oklahoma,* however, revealed numerous problems with the balloons, such as excessive time to inflate and leakage. These problems needed to be surmounted if the kite balloons were to be of real service to the navy in times of war.[23]

Aeronautical Research

Three decades after the Wrights brothers developed the basic strut-and-wire biplane, it remained the design of choice both in the United States and Europe. This design consisted of a box-like construction of two wings over each other supported in between by vertical struts and an array of crisscrossing wires. The relatively high-performance fighter airplanes of World War I were basically modified Wright Flyers. Ironically, most of the technical development of the airplane during this period took place in Europe rather than the United States, the home of the invention of the successful airplane.

Many in the U.S. aeronautical community realized that America had fallen behind European aeronautical research and needed to recapture its place in world aviation. In 1913, Charles Wolcott, the secretary of the Smithsonian, collaborated with Alexander Graham Bell, who had formed the Aerial Experiment Association (AEA), to build a practical airplane. Samuel B. Langley's aeronautical laboratory previously located in the Smithsonian was also revived and Dr. Albert Zahm became its director. As head of the Department of Physics and Mechanics at Catholic University in Washington, D.C., Zahm had conducted aeronautical experiments and been the first to build an aerodynamics laboratory at an American university. In 1901, Zahm, had built a wind tunnel at Catholic and used it to measure the aerodynamic drag on various body shapes and flat surfaces. In 1913, the Smithsonian sent Zahm and Dr. Jerome C. Hunsaker, a distinguished graduate of the Massachusetts Institute of Technology, to Europe to assess the situation. Their 1914 report "emphasized the galling disparity between European progress and inertia in the United States."[24]

This disparity and the outbreak of World War I in Europe prompted Congress to create an American agency as a matter of national security. Legislation in the Naval Appropriation Bill created the National Advisory Committee for Aeronautics (NACA) on March 3, 1915. Attached as a rider to the bill, the legislation slipped through as "a traditional example of political compromise. The legislation did not call for a national laboratory, since President Wilson apparently felt that such a move, taken during wartime conditions in Europe, might compromise America's formal commitment to strict nonintervention and neutrality."[25]

Given a small budget of only $5,000 a year, the new agency was charged with directing "the scientific study of the problems of flight with a view to their practical solution, and to determine the problems which should be experimentally attacked and to discuss their solution and their application to practical questions." The agency also determined areas that required specific research and recommended university or federal entities to undertake such projects. In the years

[23] As part of the contract, Goodyear trained two navy officers in LTA operations. Grossnick, *Kite Balloons to Airships,* 3-4. GlobalSecurity.org, "Military: AV-1 Wright," http://www.globalsecurity.org/military/systems/ship/av-1.htm (accessed June 16, 2010).

[24] Bilstein, *Enterprise of Flight,* 14. The Langley laboratory, overseen by a governing board of 11 leaders from the government, academia, and industry was dissolved in May 1914 because federal employees could not sit on the board without congressional approval. Tom D. Crouch, *Wings: A History of Aviation from Kites to the Space Age* (New York: W. W. Norton, 2003), 186.

[25] Bilstein, *Enterprise of Flight,* 14.

following its founding, NACA employees had an extraordinary amount of independence. They developed "their own research programs…handle[d] all test details in house and carr[ied] out experiments they believed appropriate."[26] Charles Wolcott eventually achieved his original goal of opening an aeronautical laboratory to serve both civil and governmental research when the NACA established the Langley Memorial Aeronautical Laboratory in Hampton, Virginia; its first building officially opened in 1917.

[26] Roger D. Launius, "The Wright Brothers, Government Support for Aeronautical Research, and the Evolution of Flight," in *Reconsidering a Century of Flight,* ed. Roger D. Launius and Janet R. Daly Bednarek (Chapel Hill: University of North Carolina Press, 2003), 58.

6. AMERICA AT WAR, 1917-1918

When the United States declared war on Germany on April 6, 1917, American military aviation lagged behind its European counterpart. While aircraft used by Pershing in Mexico had, for example, struggled to ascend through mountain passes, German multiengine bombers of 1917 could ascend so high crew members had to "suck oxygen through pipestem tubes." Moreover, despite intriguing trials involving combat applications before the war, the American military had accomplished little in the way of systematic evaluation, training, and deployment of aviation forces. In fact, many prewar "military" experiments occurred through the activities of civilian pilots.[1] Further complicating this was the fact that no single entity was in charge of military aviation. Organizations such as the Signal Corps, the government's Aircraft Production Board, and the Joint Army-Navy Technical Board all acted independently of one another. Most alarming of all, America lacked the industrial infrastructure to rapidly gear up to a wartime footing, with fewer than a dozen airplane factories and less than 10,000 skilled workers.[2]

Building an Infrastructure and Manufacturing Aircraft

America faced the monumental task of both supplying the military needs of its allies as well as providing military equipment for its own army and navy. In the year before the war, American builders had delivered 411 planes. In 1917, the Joint Army-Navy Technical Board called for 8,000 training planes, 12,400 service planes, over 41,000 engines, plus equipment—all with a delivery date of 12 months.[3] The Aircraft Production Board, an advisory body organized on May 16, 1917, and dominated by the automobile industry, set a production goal of 22,625 aircraft and engines.[4] For this board, President Wilson tapped the automobile industry with its experience in mass production rather than aircraft manufacturers with their comparatively limited production experience. Renamed the Aircraft Board in October 1917, the board oversaw production for a year while the army handled development.[5] On July 24, 1917, Congress appropriated $640 million for aircraft, and at the end of the year appropriated another $840 million.[6]

For the most part, the American aircraft industry developed few innovations in the airplane during the war. The notable exception to this was the famous Liberty engine. This was developed not by a specific company but rather by an eclectic group of industry men. Edward A. Deeds was an engineer and industrialist, who, on May 17, 1917, was appointed to the Aircraft

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[1] Daniel R. Mortensen, "The Air Service in the Great War," in *Winged Shield, Winged Sword: A History of the United States Air Force,* ed. Bernard C. Nalty (Washington, DC: Air Force History and Museums Program, 1997), 1:32, 38.

[2] Pamela Feltus, "United States Participation in World War I," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Air_Power/U.S._in_WWI/AP8.htm (accessed January 7, 2005).

[3] Roger E. Bilstein, "Flying High: The Aviation Manufacturing Industry in the United States," (2005) submitted to the National Park Service for draft *American Aviation Heritage* National Historic Landmarks Theme Study, 10.

[4] This board reported to the Council of National Defense which had been created by the National Defense Act of 1916, to expand the army in both peace and war. Congress transferred the board's control on October 1, 1917, to the War and Navy Departments and changed its title to Aircraft Board with power "to supervise and direct,…the purchase, production, and manufacture, of aircraft, engines, and all ordnance and instruments used in connection therewith." The Aircraft Production Board, *Proceedings of the Academy of Political Science in the City of New York* (Feb., 1918), 7:105, http://www.jstor.org/stable/1172205 (accessed June 11, 2010).

[5] Mortensen, "Air Service in the Great War," 45.

[6] Donald M. Pattillo, *Pushing the Envelope: The American Aircraft Industry* (Ann Arbor: University of Michigan Press, 1998), 30-31.

Production Board. "Considered the real power on the board,"[7] Deeds persuaded the U.S. government of the importance of designing and producing a standardized aeronautical engine as quickly as possible. He had several requirements for an engine of this type. It had to posses a minimum weight, and be capable of maintaining maximum power and speed during most of its operational time. It also had to be economical in the consumption of fuel and oil.

In the spring of 1917, Elbert John Hall, a partner in the Hall-Scott Motor Car Company, had just been summoned to the navy on official business. Jesse G. Vincent, vice president for engineering for the Packard Motor Car Company, was also in Washington, D.C., campaigning for the standardization of aircraft engine production. Giving Hall and Vincent the use of his suite at the famous Willard Hotel, Deeds sequestered the two engineers there on May 29. Within hours they had developed two views of a proposed eight-cylinder aircraft engine. A few days later they presented their finished drawings to the Aircraft Production Board, which approved the production of five 8-cylinder and five 12-cylinder engines for testing. Although born in six days at the Willard Hotel, the Liberty engine reflected Hall's and Vincent's years of engineering experience. Ultimately, the Liberty engine was mass-produced as a 12-cylinder engine, with a total of 20,478 units manufactured.[8]

Despite this achievement, not a single American homegrown combat airplane design saw service at the front during World War I. Of the few successful airplanes designed in the United States at that time, the Curtiss JN-4, designed as a trainer and later affectionately named the "Jenny," was probably the most effective and successful and a favored aircraft among the European Allies. Ironically, however, not even the Jenny was totally homegrown. Glenn Curtiss had commissioned an Englishman, B. Douglas Thomas, an engineer for Sopwith Aviation in Britain, to design the aircraft. The Curtiss Aeroplane and Motor Company moved from Hammondsport to a larger facility in Buffalo, New York. At peak production, around 1918, the Buffalo plant employed 18,000 workers. In 1917, Curtiss opened another large factory, this time in Garden City, Long Island. Curtiss transferred his personal headquarters and a handpicked staff of engineers to this site.[9]

The navy took a gigantic step beyond the aerodynamic laboratory at the Washington Navy Yard when it built an actual factory for the manufacture of airplanes. The Naval Aircraft Factory (NAF) opened its doors in December 1917 at the Philadelphia Navy Yard on League Island with a workforce of more than 700, and a production line for the Curtiss H-16 flying boat up and running. It was the government's first and only real airplane factory and its production line manufactured airplanes exclusively for the navy. The factory augmented the production lines of private manufacturers, such as Curtiss, while also producing new airplanes locally designed by navy aeronautical engineers at the aircraft factory. Building 77 at the navy yard is notable as the factory's assembly building.[10]

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[7] Ibid., 30.

[8] John D. Anderson, Jr., "The Growth of Aeronautical Technology in America: Principal Players, Places, and Stories," (2005) submitted to the National Park Service for the draft *American Aviation Heritage* National Historic Landmarks Theme Study, 5.

[9] C. R. Roseberry, *Glenn Curtiss: Pioneer of Flight* (Garden City, NY: Doubleday, 1972), 407; Mortensen, "Air Service in the Great War," 38.

[10] Douglas C. McVarish, "Philadelphia Naval Shipyard Historic District," National Register of Historic Places Registration Form (Washington DC: National Park Service, 1999), 4, 11, 15. In 1943 the Naval Aircraft Factory was renamed the Naval Air Material Center. In 1963 it was once again redesignated as the Naval Air Engineering Center and in 1974 relocated to Lakehurst, New Jersey. GlobalSecurity.org., "Philadelphia Naval Shipyard," http://www.globalsecurity.org/military/facility/philadelphia_nsy.htm (accessed August 3, 2004); Military

Although American firms delivered some 14,000 planes by the war's end in 1918, the record was decidedly mixed. Of roughly 6,300 combat aircraft flown by American pilots in Europe, over 5,000 came from British and French manufacturers. Most of the 1,200 combat planes of U.S. origin were British De Havilland DH-4 biplanes built under license by U.S. companies, and even these aircraft were considered obsolete by the war's end. Profiteering was partly to blame for the poor record. But, clearly, too much had been expected of the fledgling American aviation industry.

Aeronautical Research

Under the pressure of war, the National Advisory Committee for Aeronautics (NACA) became extremely busy. Limited by its annual appropriations of $5,000, the agency simply isolated and identified problems that were then turned over to other institutions and agencies to study and resolve. Thus, the NACA "evaluated aeronautical queries from the Army and conducted experiments at the Navy Yard, the Bureau of Standards ran engine tests; Stanford University ran propeller tests."[11]

Although a civilian agency, the NACA Langley Memorial Laboratory supported aeronautical research for the military services as well. However, responding to the pressures of World War I, the army had already established its own aeronautical research facility in Dayton, Ohio. McCook Field, named for the McCook family that had sent 16 members to serve in the Civil War, began operations on December 4, 1917.[12] It was America's first military aviation research and development center. The principal home of the army's Airplane Engineering Department, McCook Field provided the venue for a number of advances in aeronautical technology. For example, Frank Caldwell and Elisha Fales constructed a large wind tunnel 19 feet in length with a 14-inch diameter test section that could create an incredibly fast airspeed for that day of 465 miles per hour. This high-speed flow simulated the flow over the tips of rotating propellers. With this tunnel, in 1918, Caldwell and Fales measured the first high-speed compressibility effects for flows over airfoil shapes near or above Mach 1, the speed of sound—a tremendously important contribution to the initial study of high-speed aerodynamics.[13] The technological advancement of military aviation in America during the era of the strut-and-wire biplane would owe much to the work done at McCook Field over the next ten years.

Flying Fields

War required a vast network of aviation ground installations for training and aircraft manufacturing, testing, and repair. It also required large appropriations: $10,800,000 for fiscal year 1918 (May 1917), and $43,450,000 as a deficiencies appropriation for 1918 (June 1917). The office of the chief signal officer was in charge of planning the massive expansion of army aviation. The $640-million program Congress approved in July 1917 emphasized planes and

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Advantage, "NAES Lakehurst, New Jersey," http://www.military.com/Installation/Guides/Installation.Details?lb_installation_code=3505 (accessed August 25, 2004); Anderson, "Growth of Aeronautical Technology," 7.

[11] Roger E. Bilstein, *The Enterprise of Flight: the American Aviation and Aerospace Industry* (Washington, DC: Smithsonian Institution Press, 2001), 14-15.

[12] Mary Ann Johnson, *McCook Field, 1917-1927* (Dayton, OH: Landfold, 2002), 43.

[13] John D. Anderson, Jr., *A History of Aerodynamics and its Impact on Flying Machines* (New York: Cambridge University Press, 1997), 384. This wind tunnel is now in the collection of the National Museum of the United States Air Force in Dayton.

pilots, but flying fields to accommodate these planes and pilots were the first need. The Army Aviation Section had only three flying schools and one experimental station barely under construction. Four groups of fields were selected in phases, beginning in May to June 1917 and ending in early 1918. Three-year leases with options to purchase were the standard method of securing these fields, and in May 1917 architect Albert Kahn designed a basic airfield plan using a one-mile-square section with all buildings on one side. An extensive program of temporary wartime construction quickly rose at airfields around the country.[14]

Part of the Aircraft Production Board's mission was the recruitment of thousands of potential pilots and construction or leasing of 18 flying fields for training. To meet the ever-growing demand for more pilots, the military quickly transformed Texas prairie, Midwest farm fields and stretches of Florida sand into flying fields for would-be aviators. During the war, the army established flying fields at regular army posts such as Pope Field at Camp Bragg, North Carolina; Godman Field at Camp Knox, Kentucky; and Phillips Field at Aberdeen Proving Ground, Maryland, where aviation had not been the primary activity.[15] Established in 1917 were Carlstrom Field in Arcadia, Florida (buildings sold and removed by 1926); Ellington Field near Houston, Texas (rebuilt as a World War II training base); Scott Field [Scott Field Historic District, NR, 1994] in O'Fallon, Illinois; Wilbur Wright Field in Fairfield, Ohio; and Brooks Field near San Antonio, Texas. Even nearby Stinson Field [NR, 1975], owned and operated by Marjorie Stinson, the first female stunt pilot and the first woman to own and operate a flying school, provided pilot training.

At Brooks Field the air force maintained a dirt airfield allowing for takeoffs into any wind direction and built 16 airplane hangars, a school building, a barracks, and a line of 12 wood hangars and 4 metal hangars. Hangar No. 9 [NHL, 1976], erected in 1918 and still standing at Brooks Air Force Base, is among the oldest surviving structures testifying to the hastily created flight centers built in response to the nation's immediate need for pilots. Brooks initiated use of the British Gosport System that allowed instructors to speak with students during in-flight training, and paired individual students with the same instructor throughout their primary flight instruction. This system lessened student pilot fatalities and improved training efforts. Used in wartime training, all army flying fields quickly adopted the system.[16]

Large sums of money expended on army aviation during the war produced only temporary construction at a number of airfields—wood-frame buildings and steel-frame hangars. Langley Field and Rockwell Field, site of the Signal Corps Aviation School in San Diego, were the only stations that could claim any permanent construction at the end of the war, and 90 percent of Rockwell's construction was temporary. On November 11, 1918, the armistice brought army airfield construction work around the country to an immediate halt. Almost all airfields developed for the war effort were leased properties. Some were immediately abandoned; others were retained temporarily for demobilization as storage depots.[17]

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[14] Jody Cook, "Langley Field, Virginia: 'The Forgotten Birthplace of American Air Power'?" 1998 National Aerospace Conference Proceedings (Wright State University, April 30, 1999).

[15] Jerold E. Brown, *Where Eagles Land: Planning and Development of U.S. Army Airfields, 1910-1941* (New York: Greenwood, 1990), 65.

[16] Brooks Air Force Base, http://www.brooks.af.mil/history/timeline_1910.html (accessed April 29, 2005); George R. Adams, "Hangar 9 (Brooks Air Force Base)," National Register of Historic Places Registration Form (Washington, DC: National Park Service, 1976), Section 8. Pioneering military aviators such as Claire Chennault, Thomas D. White, Jimmy Doolittle, John Macready, William C. Ocker, Charles Lindbergh, and Nathan F. Twining all received training here.

[17] Brown, *Where Eagles Land,* 106.

Col. William "Billy" Mitchell

Air Service officer "Billy" Mitchell [General William ("Billy") Mitchell House, NHL, 1976] made one of the most significant contributions to the war effort. At the Battle of St. Mihiel, Mitchell led one of the largest bombing missions ever assembled. Mitchell had joined the army at the age of 18 and become one of the youngest officers in the Spanish-American War, but he is best known as a lifelong advocate of airpower. Assigned to the aviation section of the Signal Corps, Mitchell trained privately to become a pilot in 1916 in Newport News, Virginia. He was ordered to Europe in 1917 as a military aviation observer and became the direct commander of a multinational air force made up of 26 American, 61 French, and 3 Italian squadrons with assistance from 9 British squadrons. On September 12, 1918, Mitchell directed an airborne armada of 1,481 airplanes providing cover for Pershing's advance at St. Mihiel. This attack reflected Mitchell's belief that military airplanes should be used in overwhelming strength at specific points rather than being spread out along the Front.[18] Using one-third of his force for the direct support of frontline ground troops, Mitchell ordered the rest of the force to bomb and strafe enemy targets to the rear. As Bilstein recounts:

> Mitchell deployed his air force in a vigorous and coordinated offense, sending 500 fighters and light bombers over the front lines strafing and bombing, while two waves of 500 planes each slammed the German rear, destroying supplies, communications centers, and transportation routes and generally throwing the German war machine into disarray.[19]

During the four-day attack, the airplanes under Mitchell's command experimented with different formations and attack patterns, and scored more than 60 victories.[20] The Germans retreated in an effort to avoid being surrounded, and the Allies reclaimed the St. Miheil salient for the first time since the outbreak of the war.

Promoted to brigadier general, Mitchell applied the same bold strategy of a massive assault in the Meuse-Argonne Offensive, northwest of Verdun, which began two weeks later. But the French had withdrawn three-fourths of their air force's planes and Mitchell was forced to work with a reduced complement of 800 planes. Even so, Mitchell dispatched concentrated air attacks by large formations on the Germans' rear lines to prevent them from mounting an offensive against the American Front. The bombers, escorted by fighters, were sent deep into German territory where they met heated resistance from German fighters. Despite heavy losses on both sides, U.S. fighters strafed the German frontlines and attacked observation balloons even as they defended Allied balloons from German air attack. The Meuse-Argonne Offensive, which began at 4 a.m. on September 26, was the final battle of World War I.[21]

Capt. Eddie Rickenbacker, America's "Ace of Aces"

Capt. Edward "Eddie" Rickenbacker [Captain Edward V. Rickenbacker House, NHL, 1976], the American "ace of aces," was one of a distinguished group of aviators who could bear the title of

[18] Dick Ron and Dan Patterson, *Aviation Century: The Early Years* (Ontario, Canada: Boston Mills Press, 2003), 130.
[19] Roger E. Bilstein, *Flight in America: From the Wrights to the Astronauts,* rev. ed. (Baltimore: Johns Hopkins University Press, 1994), 34.
[20] Feltus, "United States Participation in World War I."
[21] At the time of the armistice in November 1918, the United States had 45 squadrons in France—38 of which had seen combat—767 pilots, 481 observers, and 23 aerial gunners. U.S. Air Force Museum, "St. Mihiel Offensive September 1918," http//www.wpafb.af.mil/museum/history/ww1-12.htm (accessed February 2, 2005).

"ace." A pilot became an "ace" when he had official credit—three or more eyewitnesses who observed the battle and the outcome—for the defeat of five or more enemy planes.[22] Rickenbacker, who was born in Columbus, Ohio, in 1890, began working at a garage repairing automobiles at the age of 12, shortly after his father died. He eventually left school to take a correspondence course in engineering, advancing from garage mechanic to sales before settling into auto racing in 1910. For the next six years, he was one of the nation's top race car drivers, competing in the Indianapolis 500 and establishing the world record of 134 miles per hour at a race at Daytona Beach, Florida.

When the United States entered the war, Rickenbacker applied for flight school with the U.S. Army Air Service. He was turned down because of his age and because he did not have the required college education. Instead he signed on as personal driver for Brig. Gen. John J. Pershing. In this capacity Rickenbacker was able to meet Col. William "Billy" Mitchell. Having persuaded the colonel to allow him to transfer to flight school, Rickenbacker received his wings after 17 days of training. He was then assigned to the 94th Aero Squadron in France. After further instruction by ace Raoul Lufbery, he had his first shared victory on April 29, 1918, and his first solo on May 7. Rickenbacker scored 24 more victories before the war ended. He lost several planes and sometimes returned to base with a fuselage full of bullet holes and once with a mark on his helmet from a passing enemy bullet. On September 25, he single-handedly attacked a flight of five Fokker D.VIIs and two Halberstadt CL.IIs and downed one of each type of plane. For this daring action he received the Medal of Honor, the military's highest honor.[23]

Military Ballooning Comes of Age

The army and the navy also used observation balloons, both free and tethered, during World War I. These balloons were central to the gathering of intelligence on enemy troop movements and positions, fulfilling the same role they had provided the Union Army during the Civil War.[24] In 1917, shortly after the navy's initial order of B-class ships, Goodyear started construction on facilities to support its lighter-than-air activities at their Wingfoot Lake Airship Base outside Akron, Ohio. Wingfoot Lake, known as the "Kitty Hawk of Lighter-Than-Air," is the oldest extant airship base in the United States. Besides constructing a hangar, at its own expense, Goodyear built a hydrogen-generating plant and test facilities. Wingfoot Lake also became the training site for the first class of navy airship pilots. Six hundred army and navy officers and enlisted men were trained in the operation and maintenance of B- and C-type airships, kite (observation) balloons, and free balloons. The U.S. Navy temporarily took administrative control of the facilities between 1917 and 1921 when it functioned as Naval Air Station Akron. The former Wingfoot Lake Air Ship Base was used as a test, construction, and development base and expanded to 26 buildings by the end of World War I.[25]

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[22] By the end of the war the Germans had 88 aces; England, 85; the United States, 63; France, 49; Italy 14; and Russia, 3. Eric Hodgins and Alexander F. Magoun, *Sky High: The Story of Aviation* (Boston: Little, Brown, 1929), 242.

[23] Pamela Feltus, "Eddie Rickenbacker—America's 'Ace of Aces'," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Air _Power/rickenbacker/AP9.htm (accessed January 7, 2005).

[24] Tom D. Crouch, *The Eagle Aloft: Two Centuries of the Balloon in America* (Washington, DC: Smithsonian Institution Press, 1983), 527.

[25] Roy A. Grossnick, ed., *Kite Balloons to Airships…:The Navy's Lighter-than-Air Experience* (Washington, DC: Naval Historical Center, n.d.), 7; J. Gordon Vaeth, *Blimps & U-Boats: U.S. Navy Airships in the Battle of the Atlantic* (Annapolis, MD: Naval Institute Press, 1992), 2-3. Between 1917 and 1995, out of a total of 347 airships, over 239 were assembled at Wingfoot Lake. P. Rendall Brown, "A Brief History of the Wingfoot Lake Airship Base," http://www.goodyearblimp.com/wingfoot.html (accessed February 20, 2004).

During World War I, the C-Class non-rigid was designed in response to the need for a better ASW (antisubmarine warfare) platform for convoy and patrol duties against the German U-boats. The C-Class airship saw numerous advances over its predecessor the B-Class. Among its improvements was the capacity of increased endurance for longer on-station times for convoy and patrol duties, it contained greater power and hence capacity to deal with head winds through the addition of twin engines, and an increased lift capacity allowed it to carry a larger load of depth charges. The first C-class airship was delivered to the navy at Naval Air Station Rockaway, New York, on October 22, 1918, after completing her maiden flight from Akron, Ohio. This event marked the first of a successive number of pioneering developments for the C-class airship. It was the first to carry an airplane skyward and launch it in flight. as well as the first to use helium as lifting gas. It demonstrated the feasibility of refueling from ships at sea. and also made several record-setting distance flights including a transcontinental flight across the United States. Goodrich and Goodyear Tire and Rubber Company received contracts for the construction of 30 C-class airships. With the end of the war close at hand, only 10 were built; the last two completed C-class airships were delivered on March 19, 1919. These two were subsequently transferred to the army. Nonetheless, both the B- and C-class airships were utilized during World War I for patrolling the coastline and as trainers.[26] Once the war was over, airship pilots continued their training during the interwar years using free balloons. They had proven that balloons could enhance the effectiveness of the nation's military arsenal.

World War I and its Legacy

Considering the brevity of America's role in the war, the American air combat record was impressive. The first aerial victories came on April 14, 1918, and by the November armistice, American squadrons shot down an estimated 850 planes and balloons. By the end of the war, the Army Air Service, formed around the aviation section of the U.S. Army Signal Corps when the United States entered World War I (and renamed the U.S. Army Air Corps in 1926), could muster 195,024 personnel, including 20,568 officers. The Air Service had 3,538 airplanes in Europe and 4,865 based in the United States. The navy, which had started the war with one air station at Pensacola, a complement of 48 officers (navy and marine corps combined), 239 enlisted men, 54 airplanes, 3 balloons and 1 blimp; added another 6,998 officers and 32,882 men, with a total of 2,107 aircraft, including 1,172 flying boats.[27] By the signing of the Armistice, steel and wooden hangars housing seaplanes, dirigibles, and kite balloons stretched a mile down the beach.[28]

Because America came late to the war in Europe, its contributions to World War I aviation were not as significant as those of other nations which had been forced to meet the challenge of rapidly adapting commercial flight to the new demands of warfare. The United States did, however, contribute mightily to bringing the devastating conflict to an end. In a little more than eight months, the U.S. Air Service marked 773 victories, flew 35,000 hours, and dropped 275,000 pounds of bombs.[29] By the end of the war, naval and Marine Corps aviation had trained 4,000 pilots and 30,000 enlisted personnel with pilots flying from 20 patrol bases "strung from

[26] Grossnick, *Kite Balloons to Airships,* 18; Vaeth, *Blimps & U-Boats,* 4.
[27] Bilstein, *Flight in America,* 37; Captain Albert L. Raither, "Naval Aviation: The Legacy," in Richard C. Knott, ed., *The Naval Aviation Guide,* 4th ed. (Annapolis, MD: Naval Institute Press, 1985), 4.
[28] Naval Air Station Pensacola, Florida, "The Cradle of Naval Aviation," http://naspensacola.navy.mil/history.htm (accessed June 29, 2005).
[29] Feltus, "United States Participation in World War I."

England through the Continent and south to the Azores."[30] Bilstein describes the legacy of American aviation following World War I:

> Control of the skies over the battlefield had become essential to victory in World War I, just as it would be 20 years later. Strategic aviation, if it had played little role in the 1914-1918 conflict, seemed to offer the key to victory in future wars. The fighter pilots of 1914-1918 evolved the basic techniques still used today and became the commanders of the second Great War. In both strategy and tactics the air war of 1914-1918 portended the larger aerial struggle of 1939-1945.[31]

Following the end of the war, few aircraft manufacturers survived and the nation was awash in airplanes and pilots with no ready outlet for their utility. Still, the exploits of aerial combatants such as Eddie Rickenbacker and Germany's Baron Manfred von Richthofen—the famed "Red Baron"—are an enduring legacy of World War I, ingraining images of daring pilots and their flying machines into popular culture. The film *Wings*, about two World War I "flyboys" both in love with the same girl, was awarded the first Academy Award for Best Picture in 1927. The movie, starring Clara Bow, Charles "Buddy" Rogers, and Gary Cooper, featured spectacular dogfight footage of veteran pilots in period airplanes re-creating aerial combat maneuvers, film footage that would be incorporated into World War I movies for decades to come. Both male lead actors flew their own airplanes reinforcing Hollywood's daring image of aviators.[32] So fixed is the glamorized vision of "knights of the air" fighting a personal war high above the impersonal death of the trenches, that historians caution against falling victim to such a romanticized notion:

> It was precisely this image that has been indelibly imprinted in modern memory. Scholars argue that veneration of the fighter pilot is the result of information "trivialized through popular culture, especially popular books, magazines and films," but that the most significant appropriation of this memory is to make the case for strategic bombing—a construction that "provided the framework for the planning and implementation of air power during World War II."[33]

The war advanced aviation at an astonishing pace, achieving performance gains in four years that might have taken decades to accomplish in peacetime. As a result of World War I "the small, fast, maneuverable, and heavily armed fighter emerged as a major component of the battlefield."[34] Walter Boyne argues that by 1918, after four years of vicious fighting, the fragile airplanes with which nations began to fight the first war in the air had evolved. They had become fighters capable of 130 miles per hour while carrying two machine guns, bombers capable of carrying a ton of bombs over a distance of hundreds of miles and flying at altitudes of

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[30] Bilstein, *Flight in America,* 45.
[31] John Morrow, Jr., *The Great War in the Air: Military Aviation from 1909 to 1921* (Washington, DC: Smithsonian Institution Press, 1993), 365.
[32] Roger Guillemette, "Pilots, 'Flyboys,' and Astronauts," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/socialhistory.htm (accessed February 4, 2005).
[33] Dominick A. Pisano, Thomas J. Dietz, Joanne M. Gernstein, and Karl S. Scheide, *Legend, Memory and the Great War in the Air* (Seattle: University of Washington Press, 1992), 12.
[34] Roger D. Launius, "The Wright Brothers, Government Support for Aeronautical Research, and the Evolution of Flight," in *Reconsidering a Century of Flight,* ed. Roger D. Launius and Janet R. Daly Bednarek (Chapel Hill: University of North Carolina Press, 2003), 55.

20,000 feet or more. Airplanes could now execute dives at high speeds, engage in dogfights, withstand considerable damage, and still fly.[35]

"Although its relative contribution to the war," writes Air Force historian Daniel Mortensen, "might have been small, by the end of the war, the size, technological capability, and proficiency of the U.S. military approached those of the European powers."[36] Some wondered if these capabilities exhibited in World War I would deter other wars. By November 1918, as the conflict neared its end, Wright wrote to a friend, "The Aeroplane has made war so terrible that I do not believe any country will again care to start a war."[37]

When the war ended, dozens of innovative designs were on the drawing boards, thousands of trained pilots, and a surplus of airplanes set the stage for continued advances and new uses for aircraft. All of this technology along with trained aviators and support personnel fueled a race to break speed, altitude, distance, and duration records. These advances would make possible the development of airline routes, global exploration, and a new economic sector with potential for changing the lives of ordinary citizens.[38] America's fledgling aviation industry had been transformed from a haphazard infancy into a vibrant manufacturing enterprise that would spark a national passion for flying and mark the beginning of a "golden age" of flight.

[35] Boyne, *Chronicle of Flight*, 48-49.
[36] Mortensen, "Air Service in the Great War," 37.
[37] Bilstein, *Flight in America,* 39.
[38] Ibid., 49.

PART THREE: BETWEEN THE WARS, 1918-1939

Image showing the start of the air mail service, n.d. Source: Library of Congress, Prints and Photographs Division [LC-DIG-ggbain-26825]

7. POST-WAR DEVELOPMENTS, 1918-1926

FLYING THE MAIL

The development of the airplane during World War I and aircraft's potential to move mail long distances spurred a growing interest in airmail. Before the war, in 1910, a congressional bill introducing the practicality of flying mail between New York and Washington, D.C., died in committee. Even though the postmaster general authorized local postmasters to send mail by air, at no expense to the government, and promoted airmail at a 1911 international air meet in Garden City, New York, federal funding continued to languish through 1915. Finally, in 1916, Congress approved $50,000 for the Post Office to contract with private carriers to carry the mail. Unfortunately, the first efforts to establish airmail service in Alaska and Massachusetts failed. Private companies thought the money was too little to risk their pilots and airplanes. Despite the tradition of contracting with private transportation enterprises for delivering mail over long distances, a practical airmail system needed substantial government assistance that was not forthcoming until after World War I.[1]

Otto Praeger, the second assistant postmaster general, convinced Congress to appropriate $100,000 for an experimental service between New York and Washington, D.C., during the 1917-1918 fiscal year. With the support of both the National Advisory Committee for Aeronautics, formed in March 1915 to foster aviation development, and the Standard Aircraft Corporation of Elizabeth, New Jersey, which hoped that the undertaking would provide an outlet for its aircraft products, Postmaster General Burleson approved the project.[2] Using surplus aircraft and pilots in need of employment, the War Department agreed to furnish both planes and pilots to fly the nation's first scheduled airmail service in 1918.

The Nation's First Regularly Scheduled Airmail Route[3]

For its first regularly scheduled airmail route, postal officials chose a 218-mile path between Belmont Park Race Track in Elmont, New York, and the Potomac Park Polo Grounds (West Potomac Park Polo Grounds) in Washington, D.C. The latter area was the only open flat space in the nation's capital where President Wilson and a large crowd could witness the inaugural flight. Pilots would leave Washington, D.C. and New York at the same time, land at Bustleton Field in north Philadelphia, Pennsylvania, and drop the mail. After collecting more mail, a fresh pilot and plane would complete the trips.[4]

Colonel Edward A. Deeds of the Signal Corps Reserve chose Maj. Reuben H. Fleet to manage the inaugural airmail flights.[5] On March 1, 1918, Fleet received orders to be ready to fly by May

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[1] Roger Mola, "Airmail Before 1918," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Government_Role/Pre-1918_mail/POL1.htm (accessed February 18, 2004).
[2] William M. Leary, *Aerial Pioneers: The U.S. Air Mail Service, 1918-1927* (Washington, DC: Smithsonian Institution Press, 1985), 20, 28; F. Robert van der Linden, *Airlines & Air Mail: The Post Office and the Birth of the Commercial Aviation Industry* (Lexington: University Press of Kentucky, 2002), 5.
[3] This section is based on U.S. Centennial of Flight Commission, "The Nation's First Scheduled Airmail Service, 1918," http://www.centennialofflight.gov/essay/Government_Role/1918/POL2.htm (accessed February 18, 2004).
[4] C. V. Glines, "The Airmail Takes Wing," Aerofiles: A Century of American Aviation, http://www.aerofiles.com/airmail.html (accessed July 7, 2004).
[5] van der Linden, *Airlines & Airmail*, 50-51. Deeds, a prominent industrialist in the Dayton, Ohio, community, served as a member of the Aircraft Production Board that coordinated all activities of the nation's aircraft manufacturers during the massive World War I build-up.

15. He complained, however, that no planes were capable of flying from Washington to Philadelphia and New York: "the best plane we have is the Curtiss JN-4D Jenny, and it will fly only an hour and twenty minutes. Its maximum range is 88 miles at a cruising speed of 66 miles per hour."[6] Because this aircraft could not fly even half the necessary distance, Fleet ordered the Curtiss Aeroplane and Motor Corporation to install the more powerful 150-horsepower Hispano-Suiza engines in 12 Jennys. The aircraft were also equipped with bins in the front seat to hold mailbags and extra gasoline and oil tanks for longer-range operation.

Among Fleet's experienced army pilots were Lts. Howard P. Culver and Torrey H. Webb. The Post Office insisted that Fleet add two more pilots who had political and family connections: Lts. George L. Boyle and James C. Edgerton. Both these men had recently completed flying school, but had logged very few hours in the air. The longest training flight they had completed was about 10 miles.[7] The plan was for Boyle and Culver to fly from Washington to Belmont Park, and for Webb and Edgerton to fly from Belmont Park to Washington.

The Washington to Belmont route was plagued from the start. In Washington, Fleet taped a road map to Boyle's leg showing the route from Washington's Union Station to Philadelphia. With instructions to follow the railroad tracks, Boyle tried three times to start the plane's engine, only to realize that Fleet had not refueled it. This delayed Boyle's departure by 45 minutes. When he finally took off carrying 140 pounds of mail, Boyle barely cleared the trees surrounding the small polo grounds. He then flew in the wrong direction before crashing on a farm near Waldorf, Maryland, 24 miles from the polo grounds. He was not hurt, but his mail had to be unloaded and placed on a train to Philadelphia. Instead of following the railroad tracks northward, Boyle had followed a branch line out of the rail yard that took him southeast. An unreliable compass compounded this mistake.[8]

Back at Bustleton Field, Lt. Culver waited several hours for Boyle, unaware that he had crashed and that the mail was on a train. Culver finally departed for New York at 2:15 p.m., and successfully arrived at Belmont Park carrying 200 letters. On a more successful trip, Lt. Webb departed from Belmont Park at 11:30 a.m. and arrived at Bustleton Field at 12:40 p.m., where he transferred 150 pounds of mail to Lt. Edgerton to be flown to Washington, D.C. Edgerton landed at the polo grounds at 2:30 p.m.

The Post Office Flies the Mail, 1918[9]

The U.S. Air Mail Service quickly developed an impressive record, completing an average of 91 percent of its flights.[10] In less than three months, the army had made 270 flights totaling 421 hours and 30 minutes, at an average speed of 70 miles per hour. Pilots carried 40,500 pounds of mail. Only 16 flights had to land because of mechanical failure and 53 because of bad weather. No army pilot had been killed and only a few had been injured while flying the mail.

On August 12, 1918, the army turned airmail operations over to the Post Office Department which had its own aircraft and pilots. Praeger appointed Benjamin B. Lipsner, formerly of the

[6] Glines, "Airmail Takes Wing."
[7] Ibid.
[8] Ibid.; Donald Dale Jackson, *Flying the Mail* (Alexandria, VA: Time-Life Books, 1982), 40.
[9] This section is based on U.S. Centennial of Flight Commission, "The Post Office Flies the Mail, 1918-1924," http://www.centennialofflight.gov/essay/Government_Role/1918-1924/POL3.htm (accessed February 18, 2004).
[10] van der Linden, *Airlines & Air Mail*, 5.

U.S. Army Air Service, to head the civilian-operated Air Mail Service. Conflicts with Praeger forced Lipsner's resignation in December. His replacement was Lt. Edgerton, one of the inaugural route pilots who had served during the entire three-month experiment without an accident and had only one forced landing. He had flown more trips and had more flying time (106 hours) than any of the other five pilots on the inaugural airmail route.[11]

The Post Office abandoned the polo grounds in Washington, D.C., and moved its base of operations north to the College Park Airport [NR, 1977] in Maryland, and began hiring pilots. In 1918, the department hired four pilots who each had at least 1,000 hours of flying experience. As the demand for airmail service rose, they soon hired 36 more pilots. These early airmail pilots faced many adversities. They typically flew military surplus biplanes that had been built for combat, not for long flights. Small, open cockpits meant severe cold could disorient pilots or impair their judgment, making landmark identification even more difficult. Road maps used for navigation showed large cities, but no elevations or landmarks. A simple magnetic compass could be distorted by the metal of the airplane. Flying was "a struggle of endurance and nerves."[12]

On the other hand, airmail pilot Dean Smith recalled that one of the most rewarding aspects of his job was the high pay and the large amount of leisure time.[13] Base pay came to about $3,600 per year (twice the average national wage), with an additional five to seven cents for each mile they flew. Pilots flew an average of five to six hours per day, two to three days a week. But the high pay came at a price. Recalling his decision to join the U.S. Air Mail Service in 1920, Smith said it was "considered pretty much a suicide club." By 1920, at least half of the 40 pilots had been killed while flying the mail, most in weather-related crashes. Various hazards conspired to force pilots down. Following one flight, Smith dispatched his superiors: "On trip 4 west-bound. Flying low. Engine quit. Only place to land on cow. Killed cow. Wrecked plane. Scared me. Smith."[14]

Besides weather-related crashes, military aircraft compromised pilot safety. The department replaced the slow, frail JN-4 trainers with new Standard biplanes (JR-1B) and rugged war-surplus de Havilland DH-4 light bombers.[15] At first the DH-4, designed for high-altitude military observation use, was poorly suited for use as a mail plane. These airplanes gained a morbid nickname, "Flaming Coffins," because a pilot could be easily trapped between the engine and the mail compartment in an accident. Minor crashes often turned deadly, burning entangled pilots alive. This loss of life led to the removal of the DH-4 from service in 1919 for extensive restructuring. The retrofitted de Havillands quickly became the workhorse of the airmail service and remained so throughout the first half of the 1920s, carrying more than 775 million letters in their first year. Soon, airmail pilots were assigned individual airplanes and allowed to modify them to meet their particular needs.[16]

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[11] Glines, "Airmail Takes Wing."
[12] Roger E. Bilstein, *Flight in America: From the Wrights to the Astronauts*, 3rd ed. (Baltimore: Johns Hopkins University Press, 2001), 53.
[13] Dean Smith, *By the Seat of My Pants: A Pilot's Progress from 1917 to 1930* (Boston: Little, Brown, 1961), 139.
[14] Bilstein, *Flight in America*, 53.
[15] Ibid., 50.
[16] Smithsonian National Postal Museum, "Historic Airplanes: de Havilland Workhorse of the Postal Service," http://www.postalmuseum.si.edu/airmail/historicplanes/postal/historicplanes_postal_dehavilland_long.html (accessed January 27, 2005); Jackson, *Flying the Mail*, 37.

After a year of operation, the Post Office had completed 1,208 airmail flights with 90 forced landings. Of those, 53 were attributed to poor weather and 37 to mechanical problems. At an average of $64.80 for each hour in the air, the cost to fly the mail was $143,000. Postal revenues for the year totaled $162,000. The first year of operation was the only point in the history of airmail in the United States that the service showed a profit.

Transcontinental Service[17]

Airmail service initially did not offer much of an advantage over the standard practice of sending mail by train since the cities being served were too close together.[18] Because the time saved by the speed of aircraft could only be realized over long distances, Lipsner pushed for transcontinental airmail service, beginning with the New York–Chicago route which opened on September 5, 1919. After Lipsner's resignation, Edgerton supervised the creation of an infrastructure for a transcontinental route, writing the operations manuals, and selecting and training the pilots and crew as the operation expanded westward. On May 15, 1920, airmail reached Omaha, Nebraska, via Iowa City, Iowa. By September 1920, the transcontinental route to San Francisco, California, was complete. The route followed the Union Pacific Railroad across the Rockies, via North Platte, Nebraska; Cheyenne, Rawlins, and Rock Springs, Wyoming; Salt Lake City, Utah; and Elko and Reno, Nevada.[19] Although the Post Office's schedule had called for coast-to-coast transit in 54 hours, the first trip from Long Island's Hazelhurst Field to San Francisco's Marina Airfield via Reno, Nevada, from September 8 to 11 took nearly 83 hours. Even so, that trip was heralded as an epoch-making event.[20]

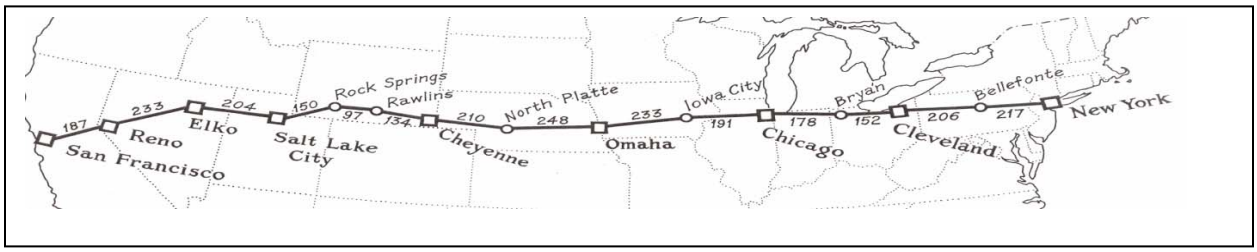
The first transcontinental flights took place only during daylight since pilots relied on visual landmarks to navigate. Neither the aircraft nor routes were equipped with measures to allow for night or poor-weather flying. At dusk, pilots landed and transferred the mail to trains that would carry it overnight until daylight allowed another plane to resume service. This combination of railroads and aircraft moved mail coast to coast in 78 hours, nearly a full day ahead of regular mail, which took 100 hours even on the fastest trains.[21] However, only randomly chosen bags of mail at specific transfer points were moved from trains to planes. "The result of each day's operations under this system," historian Nick Komos noted wryly, "was that a small fraction of the mail was given a slight kick forward."[22]

Early in 1921, Congress funded only $1.25 million of Praeger's $3.5 million request. Airmail service, critics believed, was costly, unreliable, and unsafe. Furthermore, the Post Office Department was under congressional inquiry over its use of non-airmail postal funds to support the service. To get funding, Praeger needed to convince the president, Congress, and the American people that airmail was useful, even vital, to the nation.[23] He decided to demonstrate

[17] This section is based on Roger Mola, "Transcontinental Flight and Jack Knight," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Government_Role/Knight/POL4.htm (accessed February 18, 2004).
[18] T. A. Heppenheimer, *Turbulent Skies: The History of Commercial Aviation* (New York: John Wiley & Sons, 1995), 8.
[19] van der Linden, *Airlines & Air Mail*, 6; Heppenheimer, *Turbulent Skies*, 8.
[20] William M. Leary, *Aerial Pioneers: The U.S. Air Mail Service, 1918-1927* (Washington, DC: Smithsonian Institution Press, 1985), 125.
[21] Bilstein, *Flight in America*, 50.
[22] Heppenheimer, *Turbulent Skies*, 10.
[23] Smithsonian National Postal Museum, "Airmail Creates an Industry: Creating a Nocturnal Flyway," http://www.postalmuseum.si.edu/airmail/airmail/coast/airmail_coast_nocturnal.html (accessed January 27, 2005).

how far airmail had progressed by flying both day *and* night across the country to dramatically decrease transit time. Praeger and Burleson chose President George Washington's birthday for their demonstration.

On February 22, at 6:00 a.m. EST, two airmail planes departed westward from Hazelhurst Field, and two other planes departed eastward from Marina Airfield. Relay planes waited at the regularly scheduled intermediary stops. Pilots followed bonfires, flares, and railroad tracks, such as the "iron beam" route of the Union Pacific Railroad across Wyoming and Nebraska. One pilot crashed and died, and two others were grounded due to a snowstorm in the Chicago area. Yet one transcontinental flight succeeded. Seven pilots had flown the mail 2,629 miles eastbound in 33 hours and 20 minutes, compared to 4.5 days by train.



Transcontinental Air Route, 1923. Source: Illustration by R. E. G. Davies, curator, Smithsonian National Air and Space Museum, in William M. Leary, Aerial Pioneers: The U.S. Air Mail Service, 1918-1927 (Washington, DC: Smithsonian Institution Press, 1985), frontispiece

The success of this first flight is credited to pilot Jack Knight, who flew the mail from North Platte Field [North Platte Regional Airport] in Nebraska, to Checkerboard Flying Field in Chicago. Normally other pilots waiting at stations along the route would have split the trip, but poor weather had grounded them. Knight had never flown east of Omaha, but when he learned that there was no pilot to relieve him, he drank coffee, stuffed his fur and leather suit with newspapers for insulation, and departed from Offutt Field at Fort Crook near Omaha, Nebraska, at 2:00 a.m. Bonfires, a basic compass, and a small torn section of roadmap guided him on his flight. After 830 miles, Knight connected with relief pilot J. D. Webster at Checkerboard Field. Webster left for Cleveland, Ohio, at 9:00 a.m., and Ernest Allison continued from Cleveland to New York, arriving at Hazelhurst Field at 4:50 p.m.

Transit times published in a 1923 issue of *Aeronautical Digest* illustrate the momentous achievement:

> In 1850 the fastest mail crossed the continent in 24 days, three by train and 21 by stagecoach. Ten years later, mail from the East Coast reached St. Joseph, Missouri, by train in two and a half days; Pony Express completed the trip to the West Coast in eight days. The opening of the transcontinental railroad after the Civil War sharply reduced travel time, enabling a special train in 1876 to go coast to coast in 100 hours. By 1923 regular trains took 91 hours for the trip. Now, the Air Mail Service had reduced transcontinental transit time by two-thirds.[24]

[24] Leary, *Aerial Pioneers*, 182.

The Lighted Airway

To operate on a regular basis, airmail service would require more than a string of bonfires and the "little black books" pilots used in bad weather. These books contained instructions on how to avoid hazards such as church steeples and electric lines, and even listed farms with telephones pilots could use to call for assistance after an emergency landing. Airmail pilot Bryon Moore's foul-weather formula for landing at one field on his route illustrates the dangers inherent in this type of flight:

> When you come to the fork in the road, get up on the left side to miss that silo; after you cross the railroad tracks pull up into the soup [fog], count to thirty, then let down—that way you'll miss the high tension lines; when the highway angles left, take the fourth dirt road and follow it to the ravine—just across the ravine is the airport.[25]

In 1923, Congress provided funding for a lighted airway. The second assistant postmaster general in the Harding administration, Paul Henderson, took control over the army's experimental lighted airway which had been started in 1919 with bonfires and artificial beacons between Norton Field in Columbus, Ohio, and McCook Field in Dayton, Ohio. Between July 2 and August 13, army pilots completed 25 out of 29 night flights along this airway, guided by rotating beacons and field floodlights. Henderson used this short 72-mile route as a model to light the entire transcontinental airmail route.[26]

Revolving light beacon tower being built in Omaha in the 1920s. Source: Former Object of the Month, http://www.postalmuseum.si.edu/museum/1d_Airmail_Beacon.html, Smithsonian National Postal Museum

By the summer of 1923, the first lighted airway, spanning 885 miles of the transcontinental route, was constructed on the flat terrain between Checkerboard Flying Field in Chicago and Cheyenne Airport in Wyoming, with airfields in Iowa City, Omaha, and North Platte, "each containing the most powerful artificial light ever created." Thirty-four emergency fields, with incandescent beacons, were spaced every 25 miles on the route, and 250 acetylene beacons marked the prairie route at 3-mile intervals.[27] In August, 17 de Havilland DH-4 aircraft, equipped with parachute flares, luminescent instruments, and navigation and landing lights flew this route on a four-day experimental schedule. Pilots timed their

[25] Bilstein, *Flight in America*, 53. On February 20, 1921, Praeger published the notes airmail pilots had written to describe landmarks in the *Transcontinental Air Mail Pilots' Log*, a precursor to the modern system of printed navigation aids. Mola, "Transcontinental Flight and Jack Knight."

[26] T. A. Heppenheimer, *Turbulent Skies: The History of Commercial Aviation* (New York: John Wiley & Sons, 1995), 10; Paul E. Illman, *The Pilot's Air Traffic Control Handbook* (Blue Ridge Summit, PA: TAB Books, 1993), 5; van der Linden, *Airlines & Air Mail*, 8. Corporate assistance for lighting the airway came from the General Electric Company, the American Gas Accumulator Company, and the Sperry Instrument Company. These companies helped equip aircraft with landing lights and installed powerful rotating beacons at regular and emergency fields. Leary, *Aerial Pioneers*, 174-75, 178.

[27] Leary, *Aerial Pioneers*, 178 for quote, 179.

flights to depart from either coast at dawn. They reached the lighted airway at dusk, flew through the night along its length, and then continued on the following day. The experiment was a success.[28]

Henderson next extended the lighted airway east from Chicago to Cleveland, and west from Cheyenne to Rock Springs, crossing the Appalachians and the Rockies on July 1, 1924. The system now contained more than 500 flashing gas air beacons, 89 emergency landing fields with rotating electric beacons, boundary markers, and telephones; along with 18 terminal landing fields with beacons, floodlights, and boundary markers. Progress continued both westward and eastward. One year later, the lighted airway extended from Cleveland to New York, and on February 1, 1926, from Rock Springs to Salt Lake City.[29] Unique to the United States, this overnight mail flying schedule was almost three days faster than rail delivery; it drastically cut transcontinental air delivery from 91 hours to 29 hours and 15 minutes, eastbound and 34 hours and 20 minutes westbound.[30]

Air Mail Act of 1925[31]

Under the management of the Post Office Department the airmail service had not shown any profit. Its continued growth would require substantial financing for both the manufacture of more aircraft and airway infrastructure. In 1925, Congress decided that the pioneer days were over, and that airmail had to be privatized.[32] Yet, the public, the airline industry, and the government all disagreed on how to fund the airmail system. The public wanted to spend as little as possible on stamps, but airline companies faced high costs to fly their primitive planes. President-elect Warren G. Harding threw his support behind a bill to subsidize airmail. However, companies that carried the mail by train, and who began losing business to their new competitor, objected to the government airmail subsidies.[33]

Congressman Clyde Kelly of Pennsylvania represented the rail interests and chaired a committee in the House of Representatives that controlled the appropriations of the Post Office Department. On February 2, 1925, Kelly sponsored H.R. 7064, the Contract Air Mail Bill. This bill would become the Air Mail Act of 1925, also known as the Kelly Act. Under the act, the Post Office would turn over its mail routes to commercial air carriers, which the railroad companies might buy up or control. The act also set airmail rates and the level of cash subsidies to be paid to companies that carried the mail. As Kelly explained, the act "permits the expansion of the air mail service without burden upon the taxpayers." By transferring airmail operations to private companies, the government effectively helped create the U.S. commercial aviation industry.

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[28] van der Linden, *Airlines & Air Mail*, 8.

[29] Leary, *Aerial Pioneers*, 208, shows a map of the completed routes to this point. When the Cleveland to New York section opened on July 1, 1925, the Post Office had 61 DH-4Bs equipped for night flying. Smithsonian National Postal Museum, "Former Object of the Month," http://www.postal.si.edu/museum/1d_Airmail_Beacon.html (accessed August 4, 2004).

[30] van der Linden, *Airlines & Air Mail*, 8; Heppenheimer, *Turbulent Skies*, 11.

[31] This section is based on U.S. Centennial of Flight Commission, "Airmail: The Air Mail Act of 1925 through 1929," www.centennialofflight.gov/essay/Government_Role/1925-29_airmail/POL5.htm (accessed February 18, 2004).

[32] Canadian Museum of Civilization, "A New Challenge: The 1925 Air Mail Act," http://www.civilization.ca/cpm/courrier2/cciel13e.html (accessed June 15, 2004).

[33] Heppenheimer, *Turbulent Skies*, 11.

At first, the mail contracts went to feeder lines that moved mail into the transcontinental route. Varney Air Lines operated the route between Elko Airport in Nevada, and Pasco, Washington. Ex-army major William B. Robertson, founder of Robertson Aircraft, operated the route from the Maywood Government Field in Chicago to St. Louis, Missouri. In September 1925, Postmaster General Harry S. New invited automaker Henry Ford to bid for airmail contracts along routes he already used in his business. Ford's Stout Metal Airplane Company transported auto parts to assembly plants in three cities of his industrial empire: Cleveland, Detroit, and Chicago [Ford Hangar, NR, 1983]. Ford won the routes and, on February 15, 1926, became the first to fly airmail under contract. As Will Rogers stated, "Ford wouldn't leave the ground and take to the air unless things looked pretty good to him up there."

Ford's involvement in airmail made his peers feel more comfortable about investing in similar ventures. William Rockefeller and Cornelius Vanderbilt Whitney gave start-up funds to Colonial Airlines which won the route between Boston and New York. Tycoons Philip Wrigley, Lester Armour, Charles Kettering who had invented the automobile self-starter, Marshall Field of the department stores, and Robert Lamont whose family included the secretary of commerce backed National Air Transport which served Chicago–Dallas and later Chicago–New York. Harry Chandler, publisher of the *Los Angeles Times*, and James Tolbot of Richfield Oil helped fund Western Air Express which operated between Salt Lake City and Los Angeles.[34]

Beginning in October 1925, Postmaster General New awarded eight contract airmail routes in the continental United States to seven airmail carriers. Awards went only to the largest companies that bought the largest aircraft and could accommodate both passengers and mail. Even though passengers numbered only a few hundred a year, New believed that if the airline companies carried more passengers and less mail, they could still make a profit. By the early part of 1926, contract airmail carriers flew most of the mail, but Post Office pilots and planes still flew the transcontinental route connecting San Francisco, Omaha, Chicago, and New York.

[34] Heppenheimer, *Turbulent Skies*, 12.

EARLY AIRPORT DEVELOPMENT

The airmail budget provided for pilots and planes as well as for early navigational aids and some emergency fields, but it did not allow for the establishment of a system of federally owned and operated airports. Consequently, the Post Office heavily depended upon local interests to provide the airports. Post Office officials, eager to expand the new service as rapidly as possible, now traveled the country encouraging local communities to build permanent landing facilities.[35]

Several cities responded to the Post Office's request. Aviation enthusiasts in Atlanta, Georgia, for example, had tried throughout the early 1920s to persuade the city to build an airport that would attract military aviation to the city. Although Mayor William Sims refused to act, a local landowner, Asa Chandler, responded to a request from the Post Office and in 1924, offered a lease on racetrack property he owned south of the city. This site had already hosted aviation events. Despite the mayor's continued resistance, local enthusiasts persisted and in April 1926 Mayor Sims signed a lease on the property that eventually evolved to become Atlanta's international airport.[36]

The Post Office needed an airmail airport in Chicago as mail often had to transfer from planes to trains when conditions made flying impossible; the city was also a key point in the transcontinental transport of mail by rail. Chicago also had local aviation enthusiasts eager to make their city a center for air travel. Aviation enthusiasts had built a small airport at 83rd and Cicero Avenue: Ashburn Field. It was too remote, however, to allow for the easy transfer of mail from planes to trains. Instead, the Post Office designated Grant Park**,** on the city's lakeshore and near rail facilities, as the city's official airport in 1919. Although the park had hosted numerous early aviation events, park promoters resisted the use of the park for aviation purposes. The downtown crash of a dirigible on July 21, 1919, which had taken off from Grant Park and resulted in several deaths, further discouraged the use of the Grant Park site. Post Office officials moved their operations west of the city, first to Checkerboard Field and then to Maywood Field, both privately owned facilities. Eventually, city officials, with encouragement from Charles Wacker and the Chicago Plan Commission, leased land from the board of education. After authorizing $25,000 to pay for improvements in 1926, the city established the first municipal airport at what is now Midway Airport.[37]

Omaha's aviation boosters also enthusiastically responded to the Post Office's request. Members of the local chamber of commerce, eager to add airmail to the city's transportation portfolio (it was already the headquarters for the Union Pacific Railroad), established a small landing field on a section of the AK-SAR-BEN ("Nebraska" spelled backward) exhibition grounds west of the city in 1920. Post Office officials soon found the field inadequate and in 1924 moved their operations to Fort Crook (now Offutt Air Force Base) south of the city. Airmail operations remained at Fort Crook until the late 1920s when the city, after much prompting from local civic leaders, established a municipally owned field north of the downtown area.[38]

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[35] For discussion on controversies concerning the budget (and costs) of the airmail service, see Leary, *Aerial Pioneers*, 145-59.

[36] Betsy Braden and Paul Hagan, *A Dream Takes Flight: Hartsfield Atlanta International Airport and Aviation in Atlanta* (Athens: University of Georgia Press, 1989), 16-17, 23-26, 45.

[37] David Young and Neal Callahan, *Fill the Heavens with Commerce: Chicago Aviation, 1855-1926* (Chicago: Chicago Review Press, 1981), 83-84, 145, 149-51; David Young, *Chicago Aviation: An Illustrated History* (DeKalb: Northern Illinois University Press, 2003), 71-84, 93-98, 112-16.

[38] Robert E. Adwers, *Rudder, Stick, and Throttle: Research and Reminiscences on Flying in Nebraska* (Omaha:

Although the Post Office proved the most aggressive and visible promoter of airport construction, the army's Air Service also played an important early role. Military officials also tried to persuade local interests to provide land for new military airfields during the war. With the conclusion of hostilities, they approached local groups with the goal of establishing additional facilities for use by military pilots. The need for more facilities became apparent during the war. As military pilots practicing their navigation skills traveled across the country, they often did so without adequate intermediate landing areas. Given the limited range and reliability of early aircraft, many military pilots were forced to execute emergency landings in any open space they could find.[39] After the war, the army's Air Service established two programs—the Model Airway and the Air Service Reserve Flying Field Program—to encourage the establishment of more local airports.

The first Model Airway opened between Bolling Field (now Bolling Air Force Base) in Washington, D.C., and McCook Field in Dayton, Ohio, in 1921. With prompting from the Air Service, dozens of cities and towns along the new airway—including Hagerstown and Cumberland, Maryland; Moundsville, West Virginia; and Columbus, Ohio—established some kind of landing field. The Air Service continued to map out other airways and promote local landing field construction until 1926 when the Air Commerce Act transferred exclusive responsibility for establishing and maintaining airways to the U.S. Department of Commerce's Aeronautics Branch.[40]

The Air Service also used the Reserve Flying Field Program to promote airfield construction. Established in 1921 to help reserve pilots keep their flying skills sharp, this Air Service program used War Department funds to construct facilities to train reserve military pilots. The training took place on land provided by local interests, which the Air Service leased for one dollar per year. While the program proved short-lived as military appropriations shrank in the 1920s, it did result in the construction of airports in a number of cities including Pittsburgh, Pennsylvania; Boston, Massachusetts; Kansas City, Missouri; Santa Monica, California; Cincinnati, Ohio; Louisville, Kentucky; Seattle, Washington; and Columbus, Ohio.[41]

The Air Service's contribution to early airport development went beyond the actual facilities created in response to the two airfield programs. In support of its programs, the Air Service developed and distributed a manual titled "Airways and Landing Fields." It included a map of the military airways and a section entitled "How an Airport Should Be Built." As such, it provided cities with some of the earliest how-to advice on airport construction. Though relatively simple, the manual was one of the first works on airport design.[42]

Making History, 1994), 275-316; Leslie Valentine, "The Development of the Omaha Municipal Airport, 1924-1930," *Nebraska History* 62 (Winter 1981): 403-13.

[39] U.S. Air Service, *Weekly News Letter—Week Ending Saturday, November 23, 1918* (Washington, DC): 2.

[40] U.S. Air Service, *Air Service News Letter* 5 (February 3, 1921): 1-3; Chief of Air Service, *Annual Report of the Chief of Air Service for the Fiscal Year Ending June 30, 1921* (Washington, DC: Office of the Chief of Air Service, 1921), 44; Chief of Air Service, *Annual Report of the Chief of Air Service for the Fiscal Year July 1, 1922, to June 30, 1923* (Washington, DC: Office of the Chief of Air Service, 1923), 61.

[41] Director of Air Service, *Report of the Director of Air Service to Secretary of War, 1920* (Washington, DC: Government Printing Office, 1920), 48-49; Chief of Air Service, *Annual Report of the Chief of Air Service for the Fiscal Year Ending June 30, 1922* (Washington, DC: Office of the Chief of Air Service, 1922), 31.

[42] Chief of Air Service, Airways Section, Training and War Plans Division, "Airways and Landing Facilities," *Air Information Circular* 5 (March, 1, 1923).

Although the federal government, in the form of the Post Office and the military, played an important role in early airport development, the private sector often took the lead at the local level. Though private interests remained quite active in both sponsoring and promoting airport construction, cities increasingly took on a greater role in the early 1920s. As early as 1920 few states had passed the enabling legislation necessary for cities to own and operate airports. Though most states would not take action until the late 1920s, a few state legislatures did pass laws authorizing public municipal airports before 1926. Indiana passed the first airport enabling act in 1920. The following year, the legislatures in Kansas, Nebraska, and Wisconsin followed suit. Pennsylvania and Minnesota passed laws in 1923, Washington State in 1925, and Ohio and Kentucky in 1926.[43]

Legal arguments backing public sector action on airports also emerged during this early period. In 1920, George Seay Wheat published *Municipal Landing Fields and Air Ports*, one of the first works on the subject. It included an essay by Maj. Gen. Charles T. Menoher, the chief of the Army Air Service, in which he noted that cities needed to build airports immediately lest they lose out on the economic benefits that would undoubtedly come with the new aerial age. He argued that the imminent emergence of a commercial aviation sector required the creation of a national network of airports "established under municipal control by cities and towns." Menoher's views were echoed in an article by R. Preston Wentworth in *U.S. Air Service*, which also appeared in 1920. Entitled "Have You a Little Landing Field in Your Community?", Wentworth's article argued that cities had a "civic duty" to provide airports.[44]

[43] Arnold Knauth et al., eds., *U.S. Aviation Reports, 1928* (Baltimore: U.S. Aviation Reports, 1928), 484; Joseph H. Weneman, *Municipal Airports* (Cleveland: Flying Review, 1931), 336, 346-47, 355, 357. Though the series of edited volumes produced under Knauth's editorship is the most complete source for early aviation legislation at the local and state levels, Weneman's extensive work also included reprints of many laws, regulations, and ordinances.
[44] Maj. Gen. Charles T. Menoher, "The Need for Landing Fields," in *Municipal Landing Fields and Air Ports*, ed. George Seay Wheat (New York: G. P. Putnam's Sons, Knickerbocker Press, 1920), 1-3; R. Preston Wentworth, "Have You a Little Landing Field in Your Community?" *U.S. Air Service* 4 (August 1920): 12-14.

BARNSTORMING & AIR RACES

Although World War I had brought a temporary end to civilian aviation, aerial enthusiasm soared in the postwar era. In the 1920s, "airminded" individuals used the term "winged gospel," to describe the religious fervor they felt toward aviation. Believers in the promise of flight felt that this gospel would bring about profound social and cultural changes in American society.[45] For the next three decades, two of the gospel's major tenets "helped shape the course of general aviation history." The first tenant was the popular belief that flying and owning an airplane would become as commonplace and affordable as the automobile. The second tenant was the belief that taking part in aviation "could put one on a path toward greater equality in American society," an especially appealing belief for African Americans and women who were barred from serving as military or commercial pilots.[46]

During the 1920s, barnstorming became the most popular form of flying and its popularity contributed greatly to the public's growing "airmindedness."[47] Barnstorming was also the first major form of civil aviation in the history of flight. Making this activity possible were the large supply of surplus military trainers (particularly the Curtiss JN-4 "Flying Jenny" and Standard J-1 biplanes), and the large number of former military aviators who sought a living in aviation allowed barnstorming to flourish. During the war, almost every U.S. airman had learned to fly using a Jenny. When the federal government sold its surplus $5,000 Jennys for as little as $200 during the postwar period, many of these servicemen bought their own planes.[48]

Barnstorming shows usually followed a set pattern. One or more pilots would fly over a small rural town to attract attention from local residents. After landing at a farm (hence the name "barnstorming"), the pilot would negotiate with the farmer for use of a field as a temporary runway. The pilot or team then flew back over the town in an act known as "buzzing the village," dropping handbills announcing joy rides for one to five dollars and the chance to see aerial daredevilry. For many rural towns, a barnstorming show was akin to a national holiday.[49]

One popular barnstormer of the period, Elizabeth "Bessie" Coleman, was the first licensed African American female pilot. She also "succeeded in blazing a path for African Americans in general aviation."[50] Coleman faced both racial and gender discrimination in early 20th century America. After being denied admittance to American flight schools because of her race, Coleman trained in France and on June 15, 1921, received her pilot's license from the Federation Aeronautique Internationale. Back in the United States, flying schools once again rejected her, and Coleman went back to Europe to learn standard barnstorming tricks so she could earn a living flying.[51]

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[45] Joseph J. Corn, *The Winged Gospel: America's Romance with Aviation* (Baltimore: Johns Hopkins University Press, 2002), xiii-xiv; Joseph J. Corn, "The Winged Gospel," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Social/winged_gospel/SH2.htm (accessed September 1, 2004).
[46] Janet R. Daly Bednarek with Michael H. Bednarek, *Dreams of Flight: General Aviation in the United States* (College Station: Texas A&M University Press, 2003), xi-xii.
[47] Corn, *Winged Gospel*, 12.
[48] David H. Onkst, "Barnstormers," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Explorers_Record_Setters_and_Daredevils/barnstormers/EX12.htm (accessed March 18, 2004).
[49] Ibid.
[50] Quote, Bednarek and Bednarek, *Dreams of Flight*, 15.
[51] David H. Onkst, "Bessie Coleman," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Explorers_Record_Setters_and_Daredevils/Coleman/EX11.htm (accessed March 18, 2004).

She flew in her first air show on September 3, 1922, at Glenn Curtiss Field in Garden City, New York. The *Chicago Defender*, a well-known African American newspaper, sponsored the show. The paper's publisher, Robert S. Abbott, had first encouraged Coleman to go to France. With Abbott promoting her, "Queen Bess" became an instant celebrity and one of the most famous barnstormers. She toured the country giving exhibitions, flight lessons, and lectures. She encouraged African Americans and women to learn how to fly and planned on establishing the first African American flight school.[52] However, Coleman died on April 30, 1926, after her plane went into a tailspin while practicing for a show in Jacksonville, Florida, and she was thrown to her death. In 1929, William J. Powell, a World War I army veteran and African American aviation pioneer, established the Bessie Coleman Aero Club in her honor in Los Angeles, California.[53]

Powell himself was an influential promoter of black aviation. In 1922, he earned a degree in electrical engineering, and five years later he became committed to aviation after his first airplane ride. He was convinced that black Americans should play a role in the future of aviation. "Participation in aviation, he was sure, would demonstrate what African-Americans could do, and provide the economic power that would help to break the strangle hold of Jim Crow segregation."[54]

Although barnstorming fostered great enthusiasm for aviation, fragile aircraft caused numerous accidents, fatalities, and anxiety among the public. In turn, Americans' fear of flying hampered the development of the aviation industry and the prophecies of the winged gospel. Up to this point, the federal government had played almost no role in general aviation. Safety concerns would drive the government to regulate the fledgling civil aviation business, bringing forth the 1926 Air Commerce Act, and ending the barnstorming era.

In the early 1920s, the exciting air-racing trophy contests began to steal the spotlight from the exhibition fliers, igniting unprecedented public interest in American aviation. The races "were a major inducement to aeronautical progress," and, in the words of one writer, "they proved the old horseman's adage: racing betters the breed."[55] Aviation writer Terry Gwynn-Jones describes the races as "extravagant and murderous" with "hell-for-leather fliers." She continues:

> The races had all the glitter and glamour of a Hollywood production, though some likened them more to a Roman forum with the frenzied crowd screaming at the spectacle as aerial gladiators dueled head-high around the pylons. And, as in Rome, many of the competitors died, their flaming fireball crashes adding a gory edge to the glamour. But,

[52] Valerie Moolman, *Women Aloft* (Alexandria, VA: Time-Life Books, 1981), 44.
[53] "On Labor Day 1931, the flying club sponsored the first all-black air show held in the United States, an event that attracted about 15,000 spectators." Smithsonian National Air and Space Museum, "Biographical Passage about William J. Powell," http://www.nasm.si.edu/interact/blackwings/hstudent/bio.cfm (accessed September 7, 2004).
[54] Tom D. Crouch, *Wings: A History of Aviation from Kites to the Space Age* (New York: W. W. Norton & Company, Inc., 2003), 310. In 1934, Powell wrote his autobiography *Black Wings*. In 1935, he produced the film *Unemployment, the Negro, and Aviation* about a young man who wants to be a flyer. He also created Craftsmen of Black Wings, Inc., an aviation company that offered flying lessons, and between 1937 and 1938, he published the trade journal *Craftsmen Aero-News*. University of Kentucky Libraries, "Notable Kentucky African Americans Database," http://www.uky.edu/Libraries/NKAA/subject.php?sub_id=10 (accessed October 15, 2007); Smithsonian National Air and Space Museum, "Biographical Passage about William J. Powell."
[55] Donald M. Pattillo, *Pushing the Envelope: The American Aircraft Industry* (Ann Arbor: University of Michigan Press, 2000), 39; Tom Huntington, "Racetracks in the Sky," *American Heritage of Invention & Technology* 22, no. 4 (Spring 2007): 42; Bednarek and Bednarek, *Dreams of Flight*, 13; Terry Gwynn-Jones, *Farther and Faster: Aviation's Adventuring Years, 1909-1939* (Washington, DC: Smithsonian Institution Press, 1991), 140.

> for the most part, the machines flown were try-it-and-see creations of untrained designers who mated big engines with small airframes in search of a race-winning margin.[56]

American publishing magnate Ralph Pulitzer and the Aero Club of America established the first major U.S. trophy race, the Pulitzer. Other than having entrants achieve a speed over 100 mph, there were few restrictions. "From the outset," writes Gwynn-Jones, "the military members of the Aero Club's race committee saw the race as a vehicle to promote the design of a new generation of pursuit (fighter) aircraft." Indeed, throughout the 1920s, military services viewed the races as an opportunity to advance aeronautical technology. Unlike the country's first air shows, the national air races featured government-supported military flight teams in competition with smaller groups of civilian engineer-aviators. The first race took place on Thanksgiving Day in 1920, at Mitchel Field on Long Island, New York. During the Pulitzer's six-year history, military pilots won each competition, a stance that would change in the next era.[57]

[56] Gwynn-Jones, *Farther and Faster*, 140.

[57] For quote, Gwynn-Jones, *Farther and Faster*, 141; for note of Aero Club, Bednarek and Bednarek, *Dreams of Flight*, 44; Pattillo, *Pushing the Envelope*, 39-40. Cooperation between the army and navy in the 1925 Pulitzer race resulted in the Curtiss R3C-1s, sleek racing biplanes powered by "the latest in a family of revolutionary liquid cooled engines." Huntington, "Racetracks in the Sky," 45.

COMMERCIAL AVIATION

When the day was over, my bones ached, and my whole nervous system was wearied from the noise, the constant droning of the propellers and exhaust in my ears.

—Passenger on a transcontinental flight in 1929[58]

Pioneering Passenger Service in the 1920s

Commercial aviation had emerged following World War I, but it was not until after the Air Mail Act of 1925 that airlines truly emerged. It is unclear who started the first scheduled passenger service in the United States.[59] In 1913, Sila Christofferson carried passengers by hydroplane between San Francisco and Oakland harbors. In January 1914, Thomas Benoist began carrying passengers, two at a time, in a flying boat on his St. Petersburg–Tampa Airboat line.[60] Benoist, a wealthy car manufacturer, wanted to show that airplanes could move beyond recreational or military use and serve as a regular means of transportation. Lasting only a few months, this regularly scheduled service flew passengers for five dollars per flight without a mishap until the end of the winter tourist season.[61]

For another four years no airline formed. Rather than flying, travelers chose the comfort and speed that trains offered over aircraft. In August 1919, Aero Limited started flying vacationers between New York and the New Jersey seaside resort of Atlantic City. After Prohibition made the sale of alcohol illegal nationwide, the airline began flying thirsty passengers from Miami to Nassau in the Bahamas. After some 40 flights, the airline ended operations.[62]

The first passenger service to flourish for any length of time was Aeromarine Airways run by businessman Inglis Uppercu, a former New York motorcar distributor. In 1915, Uppercu ran one of the largest aircraft manufacturing companies in the United States, the Aeromarine Plane and Motor Company, in Keyport, New Jersey. During the war, he built seaplanes for the navy. Four years later, the company used Uppercu's yacht as a terminal for sightseeing trips over New York City. Uppercu then formed Aeromarine Airways in 1920 and began offering the first regularly scheduled international passenger service from Key West, Florida, to Havana, Cuba, a route that had been part of an experimental Foreign Air Mail contract in 1920.[63] He later added other routes and, like Aero Limited, flew Prohibition-era passengers on the "Highball Express," from New York to Havana beginning in 1921.[64] Passengers on Aeromarine were among those affluent enough to pay more than double the cost of traveling by steamer or rail. Traveling on

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[58] The passenger was Edward Evans, president of Detroit Aircraft Corporation, flying in a Ford Tri-motor on a Transcontinental Air Transport cross-country flight that combined flying by day and riding trains by night. Carl Solberg, *Conquest of the Skies: A History of Commercial Aviation in America* (Boston: Little, Brown, 1979), 111.
[59] Bilstein, *Flight in America*, 26.
[60] Ibid., 26-27; Nick A. Komons, *Bonfires to Beacons: Federal Civil Aviation Policy under the Air Commerce Act, 1926-1938* (Washington, DC: Smithsonian Institution Press, 1989), 16.
[61] R. E. G. Davies, *Airlines of the United States since 1914*, rev. ed. (Washington, DC: Smithsonian Institution Press, 1982), 1; Oliver E. Allen, *The Airline Builders* (Alexandria, VA: Time-Life Books, 1981), 17.
[62] Davies, *Airlines of the United States*, 5; Komons, *Bonfires to Beacons*, 16.
[63] Davies, *Airlines of the United States*, 5-6; Allen, *Airline Builders*, 52.
[64] "The Aeromarine Website," http://www.timetableimages.com/ttimages/aerom.htm (accessed June 17, 2004). This website contains many Aeromarine Airways images. Aeromarine had absorbed an earlier airline, West Indies Airways, on this route from Key West to Havana that had been started in 1919 by one of Aeromarine's financial backers. Komons, *Bonfires to Beacons*, 16.

Aeromarine between Key West and Havana cost $50 compared to $19 by steamer, and traveling between Detroit and Cleveland cost $25 compared to $9 by rail.[65]

Souvenir postcard, circa 1922, depicting an Aeromarine Airways flight. Source: www.oldbeacon.com/gallery/gallery7/gal7-17.htm

Although financial difficulties and the fatal crash of one of its planes off the coast of Florida sent the airline out of business in January 1924, the airline had carried some 40,000 passengers in over four years.[66] According to aviation historian Roger Bilstein, Aeromarine "probably contributed more to the development of commercial air transportation than any other operation at that time, with the exception of air mail."[67] Another historian, Henry Ladd Smith, wrote, "Aeromarine had pointed the way. It became a kind of measuring stick for future passenger operations."[68] Among the airline's "firsts" in aviation history were international airmail and passenger service, in-flight movies, the creation of an airline baggage sticker, and an airline ticket office located in the McAllister Hotel in Miami.[69]

Historian Nick Komons argues that Aeromarine might have survived longer if the United States and Cuba had continued their airmail payments. "The lesson seemed clear," Komons explains, "At this stage of aviation's development, passenger service could be maintained only in combination with airmail carriage." Like Aeromarine, other early airliners failed and by 1924 commercial aviation was an "economic disaster area." Maintaining a passenger service for more than two years seemed impossible. When Aeromarine ended operations in 1924, another 64 of the 124 fixed-base operators working the previous year also ceased business.[70]

[65] Komons, *Bonfires to Beacons,* 16-17.
[66] The 1923 plane crash killed a wealthy Cuban plantation owner, two children, and a nanny. Nu-Tek Aircraft Instruments, "Aviation News and Articles: A Forgotten Aviation Pioneer Returns to Life," http://www.nu-tekline.com/aviation-news-article-one.html (accessed June 16, 2004).
[67] Bilstein, *Flight in America,* 56.
[68] Henry Ladd Smith, *Airways: The History of Commercial Aviation in the United States* (New York: Alfred A. Knopf, 1942), 87-88.
[69] Nu-Tek Aircraft Instruments, "Aviation News and Articles."
[70] Komons, *Bonfires to Beacons,* 17.

Some stability to commercial operations came with the Air Mail Act of 1925 passed in part to "encourage commercial aviation."[71] This was the first step toward the formation of commercial airlines. Among the first to be awarded contracts were companies that would evolve into the "Big Four" airlines: Colonial Airlines, later part of American Airlines; National Air Transport, forerunner of United Air Lines; Western Air Express which later merged with Transcontinental Air Transport to form Transcontinental and Western Air (later TWA); and Eastern Air Transport (later Eastern).[72]

1920s Passenger Aircraft

Among the most influential aviation investors was automobile manufacturer Henry Ford. "I feel it is now or never to get hold of commercial flying and make a success of it," Ford stated as he established an air freight service in April 1925. The editor of *Aero Digest* referred to Ford as a "master genius of industry" and declared that Ford's entry into the air carrier business "had lifted 'the dark shadow that has hung over American commercial aviation'."[73] Henry Ford first became involved in aviation in late 1923 when his son and his chief engineer expressed interest in a local inventor, William B. Stout, who had envisioned an all-metal monoplane. Ford gave Stout money to start an aircraft company. In 1924, Ford purchased the Stout Metal Airplane Company and located the company's first factory in Dearborn, Michigan. An adjacent flying field was dedicated in January 1925. From here the Stout-built 2-AT (AT stood for Air Transport) inaugurated a flight to another Ford airfield and hangar in Lansing, Michigan, becoming the world's first regularly scheduled airline devoted solely to the business of one company. Eventually, the Ford Air Transport service carried parts, mail, and personnel between three terminals [Ford Airport Hangar, NR, 1983].[74]

In 1925, Stout designed the first and only Stout tri-motor, the 3-AT. Some observers referred to the 3-AT as a "mechanical monstrosity." In January 1926, a fire destroyed the airplane factory and the 3-AT. A new factory introduced the 12-passenger Ford Tri-Motor 4-AT in July of 1926. The all-metal "Tin Goose" was the first American passenger carrier to be produced in the dozens, with nearly 200 delivered.[75] "The best-known American example of a three-engine aircraft from the 1920s and 1930s,"[76] the tri-motor was known for its durability. One pilot who

[71] H.R. 7064 (Air Mail Act of 1925/Kelly Act) as cited in Smith, *Airways*, 374.
[72] Rich Freeman, "The Pioneering Years: Commercial Aviation 1920-1930," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay_cat/8.htm (accessed March 5, 2004). Two months after the act passed, the postmaster general received 2,000 inquiries from those wanting to carry airmail. Komons, *Bonfires to Beacons*, 67.
[73] Komons, *Bonfires to Beacons*, 67.
[74] Ibid.; Heppenheimer, *Turbulent Skies*, 11; Douglas J. Ingells, *Tin Goose: The Fabulous Ford Trimotor* (Fallbrook, CA: Aero Publishers, 1968), 21-22. Pilots on these flights wore blue-and-gold uniforms and a "Flight Escort" service on each flight made sure passengers were comfortable. Stout also founded and edited *Aerial Age*, one of the earliest U.S. aviation magazines. Joe Christy, *American Aviation: An Illustrated History*, 2nd ed. (Blue Ridge Summit, PA: McGraw-Hill, 1994), 112. In 1919, Alfred Lawson, an aeronautical publisher and promoter, designed a multi-engine plane, the Lawson C-2, exclusively for passengers. Despite successful flights, the C-2's $50,000 price tag could not compete with surplus military aircraft selling for half that amount. Lawson then built the L-4, a "jumbo" airliner that could carry 34 passengers and 6,000 pounds of mail. This plane crashed on its first test flight, ending further development. Elizabeth L. Miller, "Lawson Airplane Company/Continental Faience and Tile Company," National Register of Historic Places Registration Form (Washington, DC: National Park Service, 2001), Section 8-1.
[75] R. G. Grant, *Flight: 100 Years of Aviation* (New York: Dorling Kindersley Publishing, 2002), 140; Roger E. Bilstein e-mail message to author, November 2004.
[76] John Zukowsky, ed., *Building for Air Travel: Architecture and Design for Commercial Aviation* (New York: Prestel-Verlag, 1996), 101. The 4-AT was also known as the "Flying Washboard." Ingells, *Tin Goose*, 36.

flew the 4-AT for sightseeing over the Grand Canyon recalled, "We scared the daylights out of passengers….We'd drop through the clouds and fly down a tunnel between cloud cover, river, and canyon walls. It was spooky, but safe enough. The Ford was a very forgiving airplane. She could get you out of almost anything you could get her into."[77]

At his plant, Ford turned the adjacent flying field into one of the country's most modern airports. Ford Airport had the first paved runways in the United States as well as hangars, maintenance facilities, a terminal building, restaurant, and airport hotel [Dearborn Inn and Colonial Homes, NR, 1982]. Over the main hangar, a U.S. Weather Bureau Station provided pilots with information regarding flying conditions. A radio shack located between the hangars emitted radio beacons, pioneered by Ford engineers, that guided planes to the airport from 50 miles away. The passenger terminal near the main entrance had a ticket counter, a waiting room and an esplanade for observing airport activity. In addition, future pilots received training at the airport's pilot training school. Students had a strong incentive to do well as company policy maintained the right to refuse delivery of a Ford plane to anyone who did not meet training school expectations.[78]

Although Ford built an enduring symbol of early airline travel—the Ford Tri-Motor—the company's aviation arm lost millions of dollars. A number of features in its construction, optimistically borrowed from Ford's assembly-line technology, did not make it an easy airplane for pilots to fly or airlines to operate—nor was the Ford airplane comfortable for travelers. As historian William Leary wrote, "There was nothing romantic about a Ford Tri-Motor, at least for passengers who sat inside a badly vibrating cabin, ears stuffed with cotton against the noise, clutching airsickness bags as the 100-mile-per-hour airplane bounced all over the sky." The civil market alone did not generate enough production volume to sustain profitability, even though Ford delivered some 200 models of the Tri-Motor. The Depression and problems elsewhere in the Ford industrial empire prompted the company to exit the aviation business by the mid-1930s.[79]

The 1926 Air Commerce Act

The 1920s barnstormers portrayed aviation as the realm of the thrill seeker and daredevil, not a means of safe or reliable transportation. Although passenger flight was becoming more popular, the public's fear of flying limited its full potential. To increase airline patronage and new capital for aviation development, careless "gypsy fliers" needed to be held accountable to authority. Because no laws or guidelines regulated the rational growth of aviation as a business or as a transportation system, new legislation was necessary to promote air safety and create a reliable, trustworthy airline system.[80] World War I ace Edward "Eddie" Rickenbacker believed a regulated transportation system could both tie the nation together through a system of transcontinental and north-south routes and improve the air defense system. The promotion of civil aviation would, it was believed, result in "a large body of skilled pilots, mechanics, and

[77] Another 4-AT, named the *Floyd Bennett,* flown by the Richard Byrd party over the South Pole, was later buried in snow in Little America, the main base. About 20 years later, a Byrd expedition uncovered the plane, "warmed it up, and flew it." Ingells, *Tin Goose,* 44, 45.
[78] Ibid., 28-32 (page 29 contains photo of 1929 Ford Airport).
[79] Excerpted from Roger Bilstein, "The Aviation Manufacturing Industry, 1904-1970s," prepared for the *American Aviation Heritage* theme study (Washington, DC: National Park Service, draft 2004).
[80] van der Linden, *Airlines & Airmail,* 8-11.

aeronautical engineers, as well as a vigorous airframe and engine manufacturing industry… [which] could be turned quickly to military use in the event of war."[81]

By the mid-1920s, industry leaders began calling for greater regulation. In 1925, a joint committee of representatives from the U.S. Department of Commerce and the American Engineering Council declared that flying was "unnecessarily dangerous." Orville Wright proclaimed, "I believe the examination and licensing of every pilot who engages in the transportation of passengers or merchandise for pay should be required. I also believe that proper precautions must be taken to insure the safe condition of the planes to be used." Alarming fatality statistics in 1924 provided further evidence of the need for regulation. A Senate subcommittee reported that itinerant commercial flyers had one fatal accident for every 13,500 miles flown; in comparison federally authorized Air Mail Service pilots and planes had only one fatality for every 463,000 miles flown. U.S. army pilots fared even better, leading the subcommittee to conclude, "[t]he inference is obvious."[82]

In response to these calls for federal action to improve and maintain safety standards, President Calvin Coolidge appointed a board to develop a national aviation policy in 1926. The board's report recommended a national air transportation system and Congress adopted the board's recommendations in the Air Commerce Act of 1926.[83] The act instructed the secretary of commerce to foster air commerce; to designate and establish airways; to establish, operate, and maintain aids to air navigation (but not airports); to arrange for research and development to improve such aids; to license pilots; to issue air worthiness certificates for aircraft and major aircraft components; and to investigate accidents. However, the act made no provision for the creation of a new federal aviation bureau. President Hoover maintained that the work for establishing airways could be undertaken by existing bureaus in the U.S. Department of Commerce, which would save expenses.[84] Overall, the act became the cornerstone of the federal government's regulation of civil aviation.

[81] Komons, *Bonfires to Beacons*, 29, 32-33; quote, 33.
[82] Ibid., 24-25; quotes, 24.
[83] Freeman, "The Pioneering Years"; Edmund Preston, "The Federal Aviation Administration and Its Predecessor Agencies," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Government_Role/FAA_History/POL8.htm (accessed August 19, 2005).
[84] Federal Aviation Administration, "FAA Historical Chronology, 1926-1996," http://www.faa.gov/about/media/b-chron.pdf (accessed May 19, 2005); Komons, *Bonfires to Beacons*, 81; Smith, *Airways*, 101.

8. THE GOLDEN AGE OF AVIATION, 1926-1930

Although it seemed unlikely that aviation would flourish during the Great Depression, the emergence of national aviation policy, in the form of the Air Commerce Act of 1926, put U.S. civil aviation at a "crucial dividing line in its history."[1] Under the act, the government gained responsibility for fostering air commerce, establishing airways and aids to navigation, and making and enforcing safety rules. Great progress was made. As then secretary of commerce Herbert Hoover later recounted, "We went at it with great zest." By 1929, the act had resulted in "25,000 miles of government-improved airways of which 14,000 were lighted; 1,000 airports built and 1,200 in progress; 6,400 licensed planes making 25,000,000 miles in regular flights annually; [and] a manufacturing output of 7,500 planes a year."[2] The number of airline passengers increased dramatically from 6,000 in 1926 to approximately 173,000 in 1929.[3] The public became increasingly enthralled with record-setting flights and air races, while major progress in design and engineering greatly enhanced airline development. Concurrent developments in airmail, government investigations, and airliners significantly shaped the future.

The Lindbergh Boom

Charles Lindbergh's solo nonstop transatlantic flight from New York to Paris in 1927 provided a huge boost to the popularization of aviation. As the most dramatic stimulus to the American public's air-mindedness during the early history of powered flight, Lindbergh's flight sparked "a celebration unlike anything ever witnessed in American public life."[4] In 1919, Raymond Orteig, a New York hotel owner, had offered $25,000 to the first aviator to fly nonstop from New York to Paris. Eight years later, the prize money was still unclaimed. Lindbergh, a former barnstormer and Army Air Service pilot, was a chief pilot with the Robertson Aircraft Corporation in St. Louis, Missouri. He persuaded nine St. Louis businessmen to share the $10,580 cost of a custom-built airplane so he could pursue the prize. He chose an M-2 strut-based, single-engine monoplane built by the Ryan Flying Company, which he named the *Spirit of St. Louis*. On May 20, 1927, Lindbergh taxied his aircraft down the rainy runway at Roosevelt Field in Mineola, New York. Using a magnetic compass to navigate, the 25-year-old aviator—dubbed the "Flying Kid" and the "Flying Fool" by a skeptical press corps—charted a 3,610-mile course over the Atlantic Ocean. Thirty-three and a half hours after leaving New York, Lindbergh made aviation history when he landed at Le Bourget field near Paris.

Back in New York, Lindbergh received a hero's welcome from four million people. Other cities celebrated as well. President Calvin Coolidge awarded Lindbergh the first-ever Distinguished Flying Cross, and the U.S. Congress presented him with the Congressional Medal of Honor.[5]

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[1] T. A. Heppenheimer, *Turbulent Skies: The History of Commercial Aviation* (New York: John Wiley & Sons, 1995), 88.
[2] David D. Lee, "Herbert Hoover and Commercial Aviation Policy, 1921-1933," in *Reconsidering a Century of Flight,* ed. Roger D. Launius and Janet R. Daly Bednarek (Chapel Hill: University of North Carolina Press, 2003), 94.
[3] Rich Freeman, "The Pioneering Years," U.S. Centennial of Flight, http://www.centennialofflight.gov/essay/Commercial_Aviation/1920s/Tran1.htm (accessed March 5, 2004).
[4] Joseph J. Corn, *The Winged Gospel: America's Romance with Aviation* (Baltimore: Johns Hopkins University Press, 2002), 17; quote, R. G. Grant, *Flight: 100 Years of Aviation* (New York: DK Publishing, 2002), 120.
[5] Jonathan Agronsky, "Charles Augustus Lindbergh," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Explorers_Record_Setters_and_Daredevils/Lindbergh/EX15.htm (accessed March 19, 2004).

His flight became "the turning point . . . [as] the United States took its place as the leader in world aviation for the first time since the Wright brothers."[6]

Thousands of people line the sidewalks along 16th Street in Denver, Colorado, to cheer Charles A. Lindbergh after his solo flight across the Atlantic Ocean. September 27, 1927. Source: Western History/Genealogy Department, Denver Public Library

LIGHTED AIRWAYS & AIDS TO NAVIGATION

Under the 1926 Air Commerce Act, responsibility for establishing a system of lighted airways passed from the Post Office to the Department of Commerce and its newly created Aeronautics Branch (1926-1934). In July 1927, the branch assumed responsibility for the system's still incomplete 2,612-mile transcontinental lighted airway. By the end of January 1929, the branch finished erecting beacons over the California Sierras, completing both the entire transcontinental route from New York to San Francisco, and feeder routes. A total of 4,121 miles of lighted airways now crisscrossed the U.S. For its work in developing the nation's air navigation system, the Aeronautics Branch received the 1929 Collier trophy, an annual award commemorating the most important achievement in American aviation.[7]

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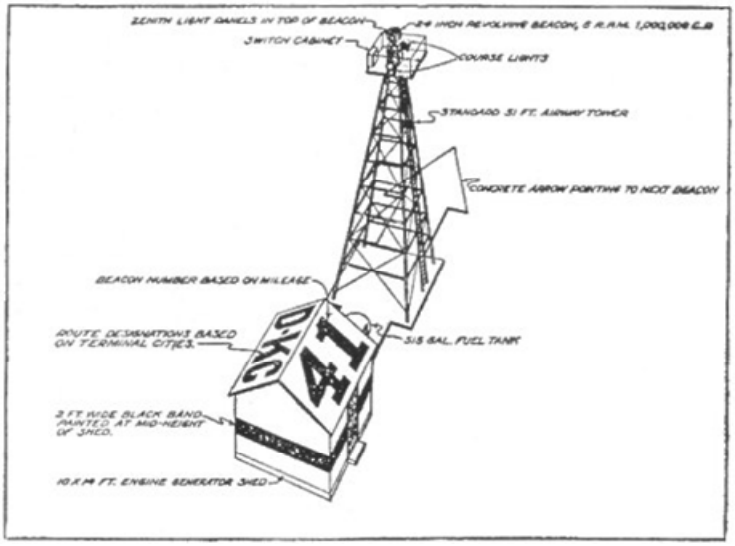
[6] Grant, *Flight*, 120. Grant also writes that Lindbergh's popularity "has never been adequately explained." Although the flight was a considerable feat, two other pilots beat Lindbergh's flight in both speed and distance only two weeks later.

[7] Scott Thompson, "The History of Flight Inspection in the United States of America," Federal Aviation Administration, http://www.naco.faa.gov/index.asp?xml=fioo/fihistory (accessed June 27, 2005); Federal Aviation Administration, "Building the Airways," http://www.faa.gov/about/history/photo_album/foundation/index.cfm?cid=building (accessed June 2, 2005). A few remaining operating rotating beacons from the 1920s and early 1930s illustrate the once revolutionary, but now archaic, navigation system. Examples include Beacon No. 0, an airway beacon in the Rocky Butte Scenic Drive Historic District [NR, 1991] in Portland, Oregon, and an aircraft beacon at Indian Mounds Park in St. Paul, Minnesota. In 1946, the airway light beacon reached its peak with 2,112 beacons in service. In the 1950s, this number declined, although some remained in operation to mark obstructions or passes. In 1973, the last airway light beacon, located on Whitewater Hill near Palm Beach, California, was decommissioned. Federal Aviation Administration, "FAA Historical Chronology, 1926-1996," http://www.faa.gov/about/media/b-chron.pdf (accessed June 2, 2005). By the early 1980s, less than 40 historic airway beacons were extant and the majority of these were not in working order. A more recent figure for extant airway beacons was not

Airway lighting in the late 1920s consisted of fixed-course lights and rotating beacons. Each beacon was mounted on a 51-foot skeleton steel tower anchored to a 70-foot concrete arrow and numbered according to their state and mileage on the airway. A small generator or equipment shed stood on the feather end of the arrow, with the beacon's number painted in large black numerals on the roof. Painted black and yellow for daytime identification, the arrow pointed in the direction of the next higher-numbered beacon, showing pilots which way they were traveling along the airway.[8]



Standard Airway Beacon Installation of the 1930s showing beacon tower in center, generator or equipment shed at feather end, and arrow to point the way. Source: Federal Aviation Administration

In the prairies and plains regions, beacon towers were typically installed in a straight line so pilots could easily follow the line of lights. A one-million-candlepower rotating light was visible to pilots up to 40 miles away in clear weather. One fixed tower light pointed to the next field, and one to the previous tower, forming an aerial roadway. The system was color coded. Green lights lit terminal and emergency landing fields. Red lights meant that no airfield was nearby or that landing conditions were unsafe.[9] Between New York and Cleveland, especially in the Allegheny Mountains, a dearth of both flat land for emergency landing fields and mountaintops accessible from the ground and visible from the air dictated a new system of airways with beacon towers erected only on the highest peaks or on buildings. The irregular placement of these beacon towers meant that pilots in the East had to rely on a compass for navigation, using the beacons only as a check.[10]

found for this theme study. David Lewis and Kathy Schutt, "Rocky Butte Scenic Drive Historic District," National Register of Historic Places Registration Form, (Washington, DC: National Park Service, 1991).

[8] Nick A. Komons, *Bonfire to Beacons: Federal Civil Aviation Policy under the Air Commerce Act, 1926-1938* (Washington, DC: Smithsonian Institution Press, 1989), 135; AvStop Online Magazine, (accessed May 26, 2005); Federal Aviation Administration, "Building the Airways."

[9] Roger Mola, "The Evolution of Airway Lights and Electronic Navigation Aids," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Government_Role/navigation/POL13.htm (accessed June 23, 2005); Smithsonian National Postal Museum, "Airmail Creates an Industry: Beacons," http://www.postalmuseum.si.edu/airmail/airmail/innovations/airmail_innovations/airmail_innovations_beacons_long.htm (accessed May 23, 2005).

[10] Komons, *Bonfires to Beacons*, 131; A. K. Lobeck, *Airways of America* (Port Washington, NY: Kennikat Press, 1933), 177.

One of the first five Flight Service Station in the United States was at Rock Springs in Wyoming originally established by the Post Office Department in 1920, was an early beacon station on the transcontinental airmail route. The facility, which operated continuously for 70 years, provided current weather information and local field condition reports to pilots, and was also a lighted emergency landing field. As aircraft technology improved, many of these early beacons and flight service stations became obsolete. The concrete arrows can still be spotted today on the rural landscape in Wyoming and Utah.[11]

Ground-to-Air Communications

The passage of the Air Commerce Act generated renewed interest in aircraft navigation systems. Before 1926, early airway radio stations had only ground-to-ground communication capability via radiotelegraph. Lacking ground-to-air communication, the National Bureau of Standards (NBS) returned in 1926 to College Park Airport in Maryland, where it had first performed experimental work to develop radio aids to navigation in 1918. Using a newly erected 70-foot wooden tower supporting two antennas and a 500-watt radio transmitter, NBS successfully conducted two-way conversations over a ground-to-air radiotelephone system that carried across distances up to 50 miles. NBS then installed a 1,000-watt radiotelephone transmitter at the Bellefonte Air Mail Field in the "hell stretch" of Pennsylvania's Allegheny Mountains. This station was strategically located on the hazardous mountainous route between New York and Cleveland where the terrain did not always permit adequate airway lighting. In August 1927, the transmitter successfully communicated with an airmail plane over 150 miles away.[12]

Beginning in the fall of 1928, two-way radio communication stations were established throughout the federal airways system. Each station had a two-kilowatt radiotelephone and telegraph transmitter, line amplifier, and two microphones. This transmitter broadcasted by voice or Morse code to aircraft. Additionally, each station had two receivers and a 400-watt crystal-controlled radiotelegraph transmitter for point-to-point communication at much higher frequencies.[13] Every plane in commercial transport service was equipped with a radiotelephone transmitter and receiver used with a trailing-wire antenna. When a pilot transmitted a radio request to find his position, two or more direction-finding stations observed the radio waves and used triangulation to determine the plane's position, which the airport then radioed to the pilot.

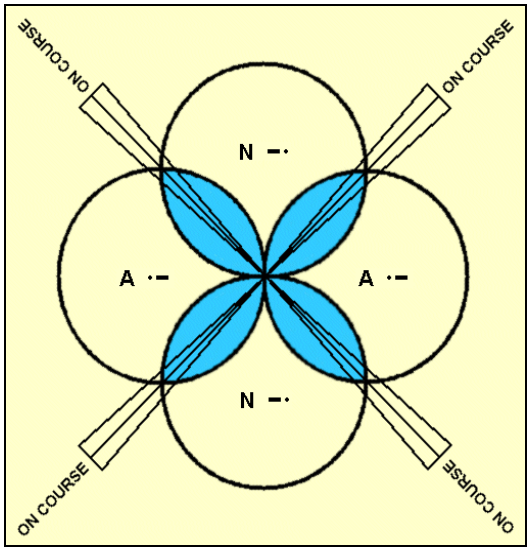
Low-Frequency Radio Range

The early two-way radio communication system between ground and air proved problematic. Little more than a homing device, it still required an airplane to carry both receiving and transmitting equipment. Additionally, ground stations could only serve one airplane at a time. In 1929, the NBS introduced a significantly improved radio navigation aid known as the low-frequency radio range (LFR), or four-course radio range. Most of the flight testing was conducted at College Park and at Bellefonte. The four-course radio range guided aircraft along a chosen course. It required only simple airborne equipment, and could provide guidance even when poor visibility rendered light beacons useless. Unfortunately, mountains, mineral deposits, railroad tracks, and even static from the atmospheric disturbance of the setting sun frequently

[11] Federal Aviation Administration, "Building the Airways"; Marilyn Maines, "History of Rock Springs Flight Service," Flight Service Station History, http://www.ama500.jccbi.gov/afss/History/FacilityPhotos/WY RockSpringsHistory.htm (accessed May 26, 2005).
[12] Komons, *Bonfires to Beacons*, 149; Mola, "Evolution of Airway Lights."
[13] Komons, *Bonfires to Beacons*, 149.

obscured audio signals. Nevertheless, the four-course radio range was a substantial improvement over dead-reckoning navigation or flashing beacons, and is considered to be the first practical radio navigation aid. This system quickly became essential to aviation, and it helped revolutionize airline transportation.[14] Airway radio stations, such as the circa 1935 Airway Radio Station [NR, 1998] in Three Forks, Montana, were the standard civil navigation aid on the U.S. airways until after World War II.

Signal equipment was housed in a small, standardized-plan building. Four nearby towers were set in a square and, because of the dual-loop antenna system used, each defined four airways. This setup created two figure-eight patterns which transmitted in Morse code the letter *A* (dot-dash), and the opposite letter, *N* (dash-dot). A pilot flying along one of the four beams toward the square would hear only an *A* or an *N* in the dashes and dots of the code. The dashes and dots grew louder or increasingly faint as he flew, depending on whether he was flying toward or away from one of the corners. Turning right or left, he would hear a different letter being transmitted, telling him which quadrant he had entered. Where the *A* or *N* signals merged, the Morse code dashes and dots sounded a constant tone, painting an audio roadway for the pilot. The overlap of the two figure-eight patterns was commonly known as "the beam," and a pilot flying on course was popularly said to be "on the beam."[15] The figures below depict a low-frequency four-course radio range, and illustrate how it worked.



The low-frequency four-course radio range was the standard aid to navigation on the civil airways from the late 1920s until after World War II. Sources: Federal Aviation Administration; Charles Wood

The New York-Cleveland airway was the first airway of any appreciable distance to have a continuous radio-marked course. Full-time operation began in November 1928, with four-course radio range stations at Hadley Field and Bellefonte. By 1933, at least 90 radio range stations were spaced about 200 miles apart along the entire New York–San Francisco airway.[16]

[14] Ibid., 154-55; National Institute of Standards and Technology, "Development of the Visual-Type Airway Radio-Beacon System," http://nv1.nist.gov/pub/nistpubs/sp958-lide/038-043.pdf (accessed June 1, 2005); Federal Aviation Administration, "Building the Airways"; Roger E. Bilstein, *Flight in America: From the Wrights to the Astronauts*, 3rd ed. (Baltimore: The Johns Hopkins University Press, 2001), 178; Mola, "Evolution of Airway Lights"; Charles Wood, "On the Beam," Flight Simulator Navigation, http://www.navfltsm.addr.com/ndb-nav-history.htm (accessed June 1, 2005).

[15] Roger Mola, "Aircraft Navigation Technology," U.S. Centennial of Flight Commission, http://centennialofflight.gov/essayEvolution_of_Technology/navigation_tech/Tech33.htm (accessed June 2, 2005); Wood, "On the Beam."

[16] Schuyler M. Gardner, "Diamond Anniversary of Airway Radio Service," TRACON, http://www.thetracon.com/

AIRPORTS

The Era of Airport Enthusiasm

During the last half of the 1920s, with the appearance of the nation's first sustained airline operations, an increased emphasis on aviation safety, and heightened public support, cities across the nation worked to build new public airports. Three events helped accelerate the shift from the private sector to the public sector on terms of airport construction: the 1925 Air Mail (or Kelly) Act, which mandated that the Post Office transfer its airmail operations to private contractors; the 1926 Air Commerce Act, which marked the beginning of federal regulation of aviation; and Charles Lindbergh's May 1927 solo flight across the Atlantic from New York to Paris.

Though private sector actors, particularly local chambers of commerce, remained influential, state legislation enabling airport construction became far more common in the late 1920s. Between 1927 and 1929, for example, at least 33 state legislatures created such laws. Most laws focused on granting local governments (city and county) the power to establish and maintain airport facilities. In some cases, though, states also carved out a role for themselves. Virginia's state government, for example, proved to be particularly interested in shaping airport development. In 1928, the state legislature passed a law requiring all airports to receive a permit from the State Corporation Commission. The intent was to ensure a semblance of order in the location of new airports. The law reflected a position taken by the Daniel Guggenheim Fund for the Promotion of Aeronautics established in 1926 to further the development of aviation in America. At a time when aircraft still suffered from range and reliability problems, the Guggenheim Fund urged the location of airports and landing fields every 10 miles along the nation's airways. Such a dense network of airports and landing fields would help ensure safe landings of aircraft experiencing mechanical failures. While the plan never received widespread support, the state of Virginia saw merit in it and hoped to shape airport location decisions in light of the plan.[17]

The Air Commerce Act of 1926 encouraged local action through its adoption of the "dock concept," which specifically made airports a local responsibility. This concept reflected the experience of local and federal governments in the development of the nation's rivers and harbors. While the improvement of rivers and harbors had been a federal responsibility, local interests (public and private) had built the docks. This meant that the federal government accepted responsibility for the development of the airways as well as the supporting communication and navigational systems; local interest would build the airports. In fact, the Air Commerce Act further emphasized the local responsibility for airports by explicitly forbidding direct federal funding for such facilities.[18]

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air%20radio%20service%20diamond.htm (accessed June 16, 2005). The range at Northway, Alaska, was the last LFR in operation until it fell silent in 1974. Federal Aviation Administration, "Building the Airways."

[17] Arnold Knauth et al., eds., *U.S. Aviation Reports, 1928* (Baltimore: U.S. Aviation Reports, 1928), 290, 494-95; Address by Harry F. Guggenheim before Governors' Conference, New London, CT, July 17 1929, Box 285, Harry F. Guggenheim Papers (hereafter HFG Papers), Library of Congress; Harry F. Guggenheim, "Safety in the Air" radio address, July 2, 1929, Box 285, HFG Papers, Library of Congress; "Virginia Realizing Plan for System of Airports," *American City* 41 (July 1929): 86; also see Richard P. Hallion, *Legacy of Flight: The Guggenheim Contribution to American Aviation* (Seattle: University of Washington Press, 1977).

[18] For a brief history of the adoption of the dock concept, see Ellmore A. Champie, *The Federal Turnaround on Aid to Airports, 1926-1938* (Washington, DC: Federal Aviation Administration, Office of Management Systems, Agency Historical Staff, 1973), 2-4.

Federal Regulation

Though the federal government could not fund airports, it did begin to regulate them under the Air Commerce Act. The act created the Aeronautics Branch within the Department of Commerce. The Aeronautics Branch and its successor organization, the Bureau of Aeronautics, undertook a regulation of airports that reflected both the progressive ideals and the associationalism current within the Hoover Administration. Robert van der Linden has argued that between 1926 and 1934 the federal government's aviation policy reflected the type of business-government relationship based on voluntary cooperation espoused by Herbert Hoover as secretary of commerce and as president. The twin goals were efficiency and standardization. Those goals, however, would be achieved not through mandate, but rather through voluntary cooperation at the local level.[19] Consequently, the Aeronautics Branch sought uniformity in airport design and construction through a voluntary program.

Given the authority to create an airport rating system, the Aeronautics Branch developed a scheme that specified a number of basic requirements for all airports. These requirements covered general equipment and facilities, size and condition of landing areas, and lighting equipment. In the first area, airports could receive an A, B, C, or D rating; in the second, a 1, 2, 3, or 4 rating; and in the third, an A, B, C, D, E, or X rating. The highest rating an airport could receive was A1A.[20] The Aeronautics Branch could not rate an airport, however, until a city (or other owner) applied for a rating. After the branch announced its program in 1928, it received requests for ratings through 1929 with the first rating issued—an A1A for the airport in Pontiac, Michigan—in February 1930. As it announced this first rating, the Aeronautics Branch also noted that several airports had withdrawn their requests because preliminary assessments indicated that they would not receive the A1A rating. These cities wished to delay the process until they could make the improvements necessary to receive "the desired rating."[21] It soon became clear that only those airports assured of a top rating applied for one. A 1932 article in *U.S. Air Service* indicated that as of that year only 5 percent of the nation's airports had applied for and been granted a rating.[22]

While the Air Commerce Act and the dock concept along with the philosophy of the Hoover Administration kept the federal government's role in airport construction minimal through the early 1930s, other factors helped promote local governmental action. Despite a trend toward greater local public action, airport formation retained a great deal of variation through the early 1930s with private initiatives continuing. And a certain regional variation was also apparent as western cities demonstrated a tendency to act more aggressively than cities in other parts of the country. The Post Office and the military remained active players, but a new actor, the commercial airlines, entered the scene.

Regional Development

In San Diego, local leaders had discussed constructing an airport as early as 1922, but only after Lindbergh's flight did they take action. Home to the company that built Lindbergh's *Spirit of St.*

[19] F. Robert van der Linden, *Airlines & Air Mail: The Post Office and the Birth of the Commercial Aviation Industry* (Lexington: University Press of Kentucky, 2002), 9.
[20] U.S. Department of Commerce, Aeronautics Branch, "Construction of Airports," *Aeronautics Bulletin* (April 1928).
[21] U.S. Department of Commerce, *Air Commerce Bulletin* 1 (February 15, 1930): 3-4.
[22] "Why Not Compulsory Ratings for Airports?" *U.S. Air Service* 17 (December 1932): 19.

Louis aircraft, the city established its airport in response to Lindbergh's epic flight. In 1927, the city proposed, and voters approved, a $650,000 bond issue. San Diego's airport proved expensive to build; the site, located near the city's harbor, required extensive dredging. The War Department, also at work on a military land field in the harbor area, reclaimed an additional 182 acres and some of that land became part of the new municipal airport. The city's Charles Lindbergh Airport opened in 1928.[23]

The construction of Oakland, California's airport [Oakland Municipal Airport] also involved military officials. In early 1927, the local chamber of commerce conducted an airport site study, presenting their findings to the city council in March 1927. Shortly thereafter, the city's Board of Port Commissioners used available funds to purchase 825 acres. Following Lindbergh's flight, the city received a visit from the War Department. In the wake of the transatlantic flight, military leaders planned a California-to-Hawaii flight. The War Department told the city it would launch this flight from Oakland if the city prepared an adequate runway on its new airport by June 24, 1927. Anxious to capitalize on the public's enthusiasm for flight, the city completed the runway in 23 days and on June 28, 1927, Lts. Lester J. Maitland and Albert F. Hegenberger took off in the *Bird of Paradise* on a 25-hour, 50-minute flight to Hawaii. By fall 1927, with financial help from the Daniel Guggenheim Fund for the Promotion of Aeronautics, the airport boasted the nation's first airport-based weather reporting station, operated by the U.S. Weather Bureau.[24]

The San Diego and Oakland stories were typical; in the late 1920s cities across the West responded particularly aggressively to build new airports. A number of historians have argued that westerners, particularly urban civic leaders, enthusiastically embraced science and a number of new technologies, including railroads, the telegraph, and irrigation works, as well as aviation. Transportation and communication technologies helped bridge the great distances between cities of the West and offered better connections between the West and the rest of the nation. Aviation had, in other words, the potential to draw the region and the nation closer together. Western leaders also sought to diversify their region's economy, and aviation offered new opportunities in the form of airlines and aircraft manufacturers. Finally, westerners had a long tradition of accepting federal programs, like the Post Office's airmail program, that they saw as providing clear benefits.[25]

A look at a number of western cities and their response to aviation supports this idea of regional variation. In Tulsa, Oklahoma, civic leaders envisioned becoming "one of the principal air centers of the Southwest." A committee led by oil executive C. C. Herndon studied other new airports and joined with other business leaders to form the Tulsa Airport Corporation. This organization financed and constructed the airport in 1928 and then presented it to the city. The resulting airport was quite impressive with an elaborate terminal building, a 100-by-120-foot,

[23] J. W. Brennan, "Lindbergh Field," *Aero Digest* 21 (September 1932): 40-41; "City and Federal Government Cooperate in Creating Extensive Airport," *American City* 38 (February 1928): 148.
[24] City of Oakland, Board of Port Commissioners, "Oakland Municipal Authority," (August 1928): 5-8; Smithsonian National Air and Space Museum Technical Files, Air Transport Series, Airport, U.S., California.
[25] Gerald D. Nash, *The American West in the Twentieth Century: A Short History of an Urban Oasis* (Englewood Cliffs, NJ: Prentice-Hall, 1973); Roger E. Bilstein, "Aviation and the Changing West," *Journal of the West* 30 (January 1991): 5-17. For more information on the West's embrace of military aviation before World War II, see Roger D. Launius, "A New Way of War: The Development of Military Aviation in the American West, 1908-1945," *American Aviation Historical Society Journal* 41 (Fall 1996): 221-23.

all-steel hangar, a large gasoline and oil serving station, an extensive airport lighting system, and parking for 10,000 automobiles.[26] The city agreed to purchase the airport in 1931 for $650,000.

In Denver, Colorado, civic leaders also dreamed of regional air prominence. Their efforts to promote aviation fit within a long tradition of civic action. When the first transcontinental railroad had bypassed the city, leaders in Denver moved quickly to build a spur line connection. Later, when the initial transcontinental airway also bypassed Denver in favor of the easier mountain crossing west of Cheyenne, Wyoming, and its airport, local entrepreneurs acted equally quickly to establish an airline to provide an air link. Municipal efforts to establish an airport dated back to 1923, but the city only acted after 1927. In that year, Mayor Benjamin F. Stapleton[27] approached the city council with a potential airport site he and Charles Vail, the commissioner of parks and improvements, had identified. Despite some opposition, the council voted in March 1928 to purchase the site and appropriated funding to develop an airport. Mayor Stapleton determined he would build the best airport the city could afford and ended up spending more than twice the original $200,000 appropriation. He and other aviation boosters argued that the new airport would secure Denver's regional importance.[28]

Though western cities were quicker to take action, cities in other regions also acted rapidly to meet new opportunities. When Transcontinental Air Transport (TAT) was formed in 1928 to create rail-air service between New York City and Los Angeles, much of the plan hinged on finding an airport with adjacent rail connections approximately 12-hours travel time by rail from New York City.[29] Columbus, Ohio, had rail service and fit within the 12-hour window. After being approached by TAT, the city purchased 320 acres of land about eight miles from downtown Columbus, along the rail line. Costing $850,000, the new Port Columbus Municipal Airport, with a terminal allowing for the easy transfer of passengers from the train to the plane, opened in August 1928, in time for the inaugural flights.[30]

Port Columbus was inaugurated July 8, 1929, as the eastern terminus for TAT's air-rail coast-to-coast service. Source: The Ohio Historical Society

[26] "Tulsa's Air Terminal," *Airports* (November 1928): 36, 39.
[27] Denver's original municipal airport, closed in 1995, was named for Mayor Benjamin F. Stapleton.
[28] Jeff Miller, *Stapleton International Airport: The First Fifty Years* (Boulder: Pruett Publishing, 1983): 5, 9, 12-15.
[29] After the night train trip from New York City to Columbus, Ohio, passengers traveled by plane to Waynoka, Oklahoma, where they transferred from the plane to a train. They traveled by overnight train to Clovis, New Mexico, where they again boarded a plane for the final leg of the journey to Los Angeles.
[30] "Choose Your Coast and Air-Rail to It," *U.S. Air Services* 13 (June 1928): 19-20; "Transcontinental Air-Rail Service Becomes a Fact," *U.S. Air Services* 14 (July 1929): 22-23; Dr. R. Lane, "A New Air Harbor in Central Ohio," *Airports* 3 (August 1929): 25-26, 48-49; "Where Plane and Train Meet," *U.S. Air Services* 14 (July 1929): 24.

According to historian R. E. G. Davies, "the formation of TAT marked a definite step in the progress of civil aviation in the United States." The group chose Charles Lindbergh as chairman of its technical committee, a choice that resulted in TAT's nickname, the "Lindbergh Line." Lindbergh planned TAT's transcontinental route. Some existing airports were chosen and others were built en route.[31] Passengers using the grueling two-day service flew by day and traveled by train at night. Service began with an overnight train from New York to TAT's terminus at Port Columbus. From the railway station, passengers walked along a covered walkway to the Port Columbus airport terminal and flew to Waynoka, Oklahoma [Santa Fe Depot and Reading Room, NR, 1974] with 10 stops along the way in cities such as Indianapolis, St. Louis, Kansas City, and Wichita. After dining at the Harvey House in Waynoka, passengers then traveled by the Atchison, Topeka & Santa Fe Railroad to Clovis, New Mexico. From there they flew to Los Angeles arriving at the Grand Central Air Terminal in Glendale (via Albuquerque, Winslow, and Kingman). The entire 48-hour plane/train trip was one day shorter than rail travel.[32]

Though most cities increasingly chose to own their airports beginning in the late 1920s, a number of cities continued to lease airport sites. Chicago, as noted earlier, leased the site for its new municipal airport from the local board of education. Los Angeles was well served by a number of private airports, but following the passage of the necessary enabling legislation in 1927, the city began exploring the possibility of building a public airport. The city council decided upon a site in Inglewood, already scheduled to host the National Air Races that year. After that event, the city began the development of Mines Field, named for the local real estate developer who had played a central role in the site selection process. Because an attempt to pass a bond issue failed, the city decided to lease rather than buy the property. On September 25, 1928, the city created the Los Angeles Department of Airports to build and manage the new airport and the city signed a lease for the property the following day.[33]

Airport construction flourished between 1926 and 1930. This activity forced all levels of government—local, state, and national—to respond to the demand for air facilities. For the most part, local governments emerged as the primary actors because the Air Commerce Act precluded direct federal action and courts defined airports as a public responsibility. Private sector initiatives, though, remained. The enthusiasm that fed this period of intense activity began to dampen by the early 1930s as the economic depression that gripped the nation after 1929 strained municipal budgets. During this period, technological advances allowed for increased

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[31] R. E. G. Davies, *Airlines of the United States since 1914*, rev. ed. (Washington, DC: Smithsonian Institution Press, 1982), 81-83. TAT "was backed by Keys' associated companies, the Curtiss Aeroplane and Motor Company, the Wright Aeronautical Corporation, and National Air Transport; the Pennsylvania Railroad; and a group of bankers and businessmen from St. Louis, a city which has been a strategic point in the company's route network ever since." TAT was not the first to offer transcontinental air-rail service. Three weeks earlier in June 1929, Universal Aviation Corporation operated a 67-hour air-rail service between New York and Los Angeles. In August 1929, after TAT started its service, Standard Airlines ran a third air-rail system that took the same time as Universal. Davies, *Airlines of the United States*, 80, 112.

[32] Donald J. Ingells, *Tin Goose: The Fabulous Ford Trimotor* (Fallbrook, CA: Aero Publishers, 1968), 46, 47-48; Grant, *Flight*, 138-39; Oliver E. Allen, *The Airline Builders* (Alexandria, VA: Time-Life Books, 1981), 70, 72-79; Carl Solberg, *Conquest of the Skies: A History of Commercial Aviation in America* (Boston: Little, Brown, 1979), 112; Asif Siddiqi, "Trans World Airlines (TWA)," U.S. Centennial of Flight Commission http://www.centennialofflight.gov/essay/Commercial_Aviation/TWA/Tran14.htm (accessed March 5, 2004); Davies, *Airlines of the United States*, 81-85. Unable to make a profit, the service ended in 1930, but the airline is recognized as the first cross-country passenger service without a mail subsidy. To pilots, TAT stood for "take a train." Solberg, *Conquest of the Skies*, 110.

[33] Paul D. Friedman, "Birth of an Airport: From Mines Field to Los Angeles International, L.A. Celebrates the 50th Anniversary of Its Airport," *Journal of the American Aviation Historical Society* 23 (Winter 1978): 288-89.

flights and flights under inclement weather conditions, but they also made airports more complex and expensive to build and maintain. Finally, cities faced new court challenges that raised issues of liability and nuisance. Airport development did not stop, but by the early 1930s cities faced a new, harsher reality.

9. THE GOLDEN AGE OF AVIATION, 1930-1939

A NATIONAL NETWORK OF AIR ROUTES

Airmail and the 1930 McNary-Watres Act[1]

After passage of the 1926 Air Commerce Act which emphasized the development of commercial aviation, the Postmaster General considered turning the transcontinental airmail route over to private contractors. The department advertised two routes: one from New York to Chicago and the other from Chicago to San Francisco. Boeing took over the western sector between Chicago and San Francisco on July 1, 1927, and National Air Transport took over the eastern sector between New York and Chicago two months later. On September 1, 1927, government-operated air mail service came to an end. A new and highly controversial system in airmail contracts was about to begin under Herbert Hoover's new postmaster general, Walter Folger Brown; this would produce a systematic air transportation network.

Appointed postmaster general in 1928, Brown found much of the airmail system inefficient and costly. By 1929, a hodgepodge of companies comprised the transportation system of which 44 companies flew 53 established routes. Only 10 routes covered more than 500 miles, while just 2 routes exceeded 1,000 miles. He believed the system could be improved by awarding contracts to financially sound and capable firms that could also carry passengers over long major transcontinental and north-south routes. Both Brown and Hoover saw strong commercial aviation as essential for national defense.[2] To change existing policy, Brown sought congressional authority to create a stable and efficient air transport system for both passengers and the mail. On April 2, 1930, Congress passed the McNary-Watres Act, also known as the 1930 Air Mail Act. As Hoover later explained on May 2, 1930, the purpose of the act was "to encourage passenger traffic and to bridge over from solely a postal aviation to passenger carrying airplanes."[3]

The act's main provision changed how airmail payments were calculated in a manner that encouraged airlines to seek passenger revenue. Airmail carriers were to be paid up to $1.25 per mile if the cargo capacity of their plane was at least 25 cubic feet, even if the plane flew empty. The rate per mile was less for planes with less capacity. Airlines no longer had an incentive to carry mail since they would receive the same amount of money for a plane of a certain size whether it carried mail or not. However, because airlines could easily earn additional revenue by charging passengers, they began using larger planes that could accommodate more people, such as the 14-passenger Douglas DC-2 and the 8- to 15-passenger Ford Tri-Motor.[4]

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[1] This section is partially based on U.S. Centennial of Flight Commission, "Airmail and the Growth of the Airlines," http://www.centennialofflight.gov/essay/Government_Role/1930-airmail/POL6.htm (accessed February 18, 2004).
[2] David D. Lee, "Herbert Hoover and Commercial Aviation Policy, 1921-1933," in *Reconsidering a Century of Flight,* ed. Roger D. Launius and Janet R. Daly Bednarek (Chapel Hill: University of North Carolina Press, 2003), 97; T. A. Heppenheimer, *Turbulent Skies: The History of Commercial Aviation* (New York: John Wiley & Sons, 1995), 32-33.
[3] Lee, "Herbert Hoover," 102.
[4] David Donald, ed., *The Complete Encyclopedia of World Aircraft* (New York: Barnes & Noble Books, 1997), 444; Smithsonian National Air and Space Museum, "Ford 5-AT Tri-Motor," http://www.nasm.si.edu/research/aero/aircraft/fordtri.htm (accessed January 3, 2005).

A second provision of the McNary-Watres Act allowed any airmail carrier that had operated for at least two years to exchange its mail contract for a route certificate giving them the right to carry mail for another ten years. The third and most controversial provision gave the postmaster general authority to extend or consolidate routes when the postmaster general determined it to be in the public interest. Brown now had almost dictatorial powers over the air transportation system.

Under the act, Brown, who disliked reckless competition and monopolies, compelled small companies to "merge or die" through a form of selective regulated competition.[5] In what later became known as the "Spoils Conference," Brown presented his airway map to invited leading aviation executives and proposed that they trade routes or merge to bring the airway map to fruition. In the end, 20 of the 22 contracts went to the "Big Four" airlines: T&WA (merger of Transcontinental and Western Air), American, United, and Eastern.[6] Brown also awarded two bonuses to airlines: one, if the airline carried more passengers, and another, if the airline bought larger aircraft powered by more than one engine and equipped with two-way radios and navigation aids.

Brown's role in engineering airline mergers in 1929 and 1930 helped to create a systematic air transportation system that served for several years.[7] By 1933, eight north-south lines and three transcontinental routes tied the nation together.[8] However, small aviation companies could not compete and complained that they had been omitted from Brown's scheme. The next president, Franklin D. Roosevelt, decided to investigate.

In 1933, Congress, under a new Democratic administration, questioned the process by which the Post Office had awarded its airmail contracts under the McNary-Watres Act. Alabama Democratic senator Hugo Black established a committee to hold hearings beginning in January 1934. These hearings depicted the former postmaster and the large aviation companies as corrupt and greedy, with Black referring to the practice of giving contracts as "spoils," and arguing that business had gone only to friends of the Hoover Administration. Former Postmaster Brown justified his reasoning to Congress by referencing his own flying experience and great concerns for passenger safety.[9] In regard to awarding contracts to those with higher bids, Brown stated: "There was no sense in taking this government's money and dishing it out, giving it out as a handout to every little fellow that was flying around the map and was not going to do anything or could not do anything to develop aviation in the broad sense."[10] He elaborated:

> I could think of no other way to make the industry self-sustaining; make it economically independent; than to compel the air mail contractor to get some revenue from the public.

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[5] Rich Freeman, "Walter Folger Brown: The Postmaster General Who Built the U.S. Airline Industry," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Commercial_Aviation/Brown/Tran3.htm (accessed March 5, 2004).
[6] F. Robert van der Linden, "Progressives and the Post Office: Walter Folger Brown and the Creation of United States Air Transportation," in *From Airships to Airbus: The History of Civil and Commercial Aviation*, ed. William F. Trimble (Washington, DC: Smithsonian Institution Press, 1995), 2:252.
[7] Freeman, "Walter Folger Brown."
[8] Lee, "Herbert Hoover," 106.
[9] No stranger to flying, Brown himself rode a portion of T&WA's first contract flight in a Ford Tri-Motor from Newark to Harrisburg. Henry Ladd Smith, *Airways: The History of Commercial Aviation in the United States* (New York: Alfred A. Knopf, 1942), 273.
[10] Oliver E. Allen, *The Airline Builders* (Alexandria, VA: Time-Life Books, 1981), 90.

> Almost all of them were refusing to carry passengers and were depending wholly upon the Post Office department and we were getting nowhere in the development of airplanes. They were just using little, light, open-cockpit ships to move mail, with very great dependability, but no progress in a broad sense was being made in the art.
>
> I believed that it was my duty to force them, if I could under the law, to get revenue from non-postal sources, and the obvious one was passengers; and after we could get the people flying themselves…we thought then they would send their freight…by planes, and the purpose of it was altogether to help develop an industry that could live without a subsidy—that could live on its own.[11]

Another requirement for an operator to compete for an airmail contract was night-flying experience. Brown went on to explain his reasoning:

> [B]ecause of the reluctance of these other people to fly passengers, I did everything I could think of to make the operation safe. I thought experience in night flying was essential.… That is why I put [the night-flying clause] into the advertisement and took responsibility for it…because one major disaster at that time…would have ruined the whole thing I was trying to do.[12]

Dismissing Brown's justifications, the chief postal attorney recommended that Roosevelt cancel the airmail contracts. After consulting further with the attorney general and the Army Air Corps, in February 1934, Roosevelt announced that the Air Corps would fly the mail. The decision struck hard at the commercial airlines, inflicting large losses. To cope, airlines drastically cut their service and TWA furloughed its entire staff.[13]

The army's early attempts at flying the mail proved disastrous. Military pilots had not received training to fly at night or in bad weather and their aircraft were not equipped with the safety features present in commercial aircraft. During training, three pilots died, and a winter storm during the first week of operation killed two more pilots, injured another six, and destroyed eight planes. More accidents occurred even as the Air Corps began using new planes, such as the Martin B-10. By March 10, 1934, an alarming 12 army pilots had died in 66 crashes or forced landings. Eddie Rickenbacker, a former World War I pilot nicknamed Ace of Aces and president of Eastern Air Transport, condemned the situation in the *New York Times* referring to it as "legalized murder."[14] Facing public and media outrage, Roosevelt quickly reversed his decision and the airlines began carrying the mail again. However, the president excluded from the new contracts those airline executives who had been present at the "Spoils Conference" and received an airmail contract in 1930. To circumvent this exclusion, the airlines simply changed

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[11] Smith, *Airways*, 271, quoting from "Testimony of Walter Folger Brown," Special Committee on Investigation of the Air Mail and Ocean Mail Contracts, United States Senate, 73d Congress, Second Session, 2569-74.
[12] Ibid., 275, 276.
[13] Heppenheimer, *Turbulent Skies*, 57, 58, 60. Later, in 1941, all allegations of corruption against former Postmaster Brown were dropped.
[14] F. Robert van der Linden, *Airlines & Airmail: The Post Office and the Birth of the Commercial Aviation Industry* (Lexington: University Press of Kentucky, 2002), 277. C. V. Glines, "Captain Eddie Rickenbacker," The History Net, http://www.historynet.com/ahi/blcaptaineddie/index1.html (accessed June 28, 2004). To show that airlines were better qualified to fly the mail than Air Corps pilots, Rickenbacker, along with Jack Frye, vice president of TWA, and a group of journalists, made a transcontinental flight in a Douglas DC-2 in 13 hours and 4 minutes, setting a record for commercial planes. Donald, *Complete Encyclopedia of World Aircraft*, 357.

their names: American Airways became American Air Lines, Northwest Airways became Northwest Airlines, Eastern Air Transport became Eastern Air Lines, and T&WA became TWA, Inc.[15]

The Air Mail Act of 1934

In response to these airline name changes, Senator Hugo Black introduced the Black-McKellar Bill which became known as the Air Mail Act of 1934. The act forbade aviation holding companies that owned both aircraft manufacturing companies and airlines from bidding on airmail contracts, and authorized the government to set airmail contracts, routes, and schedules, fix subsidy rates and payments, regulate the airways, and license pilots. To ensure that the airlines operated strictly in accordance with the public interest, the Interstate Commerce Commission (ICC) assumed responsibility for determining what constituted public convenience and necessity. After December 31, 1934, all aviation holding companies were forbidden from receiving a federal subsidy through airmail. Heavily dependent on the subsidy, the companies were forced to separate air transportation systems and aircraft manufacture from the holding companies.

Faced with declining revenue and the ICC's inability to handle aviation matters satisfactorily, U.S. airlines struggled from 1934 to 1938.[16] Nevertheless, airline service grew quickly because of improvements in aeronautical technology and the manufacture of new aircraft that could carry both mail and passengers. New Boeing and Douglas planes accommodated passengers more comfortably with soundproofing and conveniences such as heating and cooling. Flying became easier for pilots with the introduction of the Sperry Gyroscope automatic pilot and dual flight instruments. These improvements made regularly scheduled day and night service commonplace, and aircraft could now fly overseas, making international airmail service possible. The first airmail flight across the Pacific Ocean occurred in 1935 when a Martin M-130 made a 59-hour flight from San Francisco, California, to Manila in the Philippines.

What the U.S. Post Office Department began in August 1918, simply as a means of moving the mail efficiently to serve the needs of national commerce and communication, ultimately became today's global system of passenger airlines.[17] The ability to move people and goods over vast distances by air became one of the greatest social and technological achievements of the 20th century.

[15] United Airlines retained its original name, but was no longer able to operate as a managing company because of its transition into an operating airline. Its former four component parts were now part of one legal entity. van der Linden, *Airlines & Air Mail*, 284.
[16] Ibid., 290.
[17] Ibid., 2.

NEW ERAS IN PASSENGER AVIATION

The majority of Americans still remained convinced in the 1930s that any man or woman who lifted an airplane to the clouds had bade farewell to common sense, caution, and the right to call anyone else audacious.

—Carl Solberg[18]

Transoceanic Commercial Flight[19]

Pan American, which flew international routes, free of competitive bidding, emerged unscathed from the domestic airmail cancellations. The government awarded Pan Am every foreign airmail route for which bids were invited and viewed Pan Am as its "chosen instrument" for foreign policy. The government used the airline to facilitate economic expansion into Latin America and the Caribbean.

Pan Am's history is inseparable from the life and career of Juan Trippe, Pan Am's founder and guiding visionary for five decades. A former navy pilot, Trippe had shown early interest in passenger aviation with an aborted attempt to start a charter service for wealthy New England socialites in the early 1920s. With the help of financiers such as Cornelius Vanderbilt Whitney and William Rockefeller, Trippe formed the Aviation Corporation of America on June 2, 1927, to offer air services into the Caribbean. Trippe became president and general manager of Pan American, the operating subsidiary.[20] The new firm had "two planes, a little ticket office in the arcade of Havana's Biltmore Hotel and another at the Key West airport, and a three-room headquarters office on New York's 42nd Street."[21]

In the 1930s, during the golden age of the flying boat, Trippe became the major driving force behind the founding of Pan American's Clipper service. By 1930, pioneer flyers had laid the foundation for transoceanic routes, but, as aviation journalist and former aviator Robert L. Gandt, points out, "not one major civil airport yet possessed a long, flat, paved surface sufficient to accommodate the weight of an oceangoing transport plane." Designers rose to the challenge to create the golden age of flying boats.[22] These planes had several advantages over land planes in long-distance travel: they needed no chain of airfields, their boatlike hulls gave assurance to ocean-flying passengers, and they were roomier than land planes.[23] In the history of American

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[18] Carl Solberg, *Conquest of the Skies: A History of Commercial Aviation in America* (Boston: Little, Brown, 1979), 173.

[19] Portions of this section are excerpted or paraphrased from Asif Siddiqi, "The Beginnings of Commercial Transatlantic Services," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Commercial_Aviation/atlantic_route/Tran.4.htm (accessed March 5, 2004); Asif Siddiqi, "Pan American's Flying Boats," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Commercial_Aviation/china_clipper/Tran5.htm (accessed March 5, 2004); Asif Siddiqi, "Pan American: The History of America's 'Chosen Instrument' for Overseas Air Transport," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Commercial_Aviation/Pan_Am/Tran12.htm (accessed March 5, 2004).

[20] The corporation was a merger of Trippe's two competitors. The first, Atlantic, Gulf, and Caribbean Airways formed on October 11, 1927, and was headed by Richard Hoyt, a New York broker. The second was founded by several army officers including Maj. Henry H. "Hap" Arnold, who would head the U.S. Army Air Force during World War II and had formed an airline called Pan American Airways on March 14, 1927. Siddiqi, "Pan American."

[21] Oliver E. Allen, *The Airline Builders* (Alexandria, VA: Time-Life Books, 1981), 146.

[22] Maurice Allward, *An Illustrated History of Seaplanes and Flying Boats* (New York: Dorset, 1981), 81; Robert L. Gandt, *China Clipper: The Age of the Great Flying Boats* (Annapolis: Naval Institute Press, 1991), ix.

[23] R. G. Grant, *Flight: 100 Years of Aviation* (New York: DK Publishing, 2002), 157-58.

commercial aviation, the Pan American Airways flying boats occupy an important place. The planes were part of an ocean wide network that set a host of aviation records as part of the famous Clipper Ships service. With its fleet of 25 flying boats, Pan American became the first airline to cross the Pacific, the first to establish extensive routes in South America, and the first to offer regular airplane commercial service across the North Atlantic.

Needing a modern amphibious plane, Trippe turned to famous aviation designer Igor Sikorsky. Sikorsky, who had produced the 10-seat Sikorsky S-38 now produced the first four-engine seaplanes for Pan American, the Sikorsky S-40 and the S-42. The S-40 could carry 50 passengers with a range of nearly 1,000 miles. The S-42 tripled the S-40's range and was the world's first big luxury airliner.[24] It was also the "first airplane ever to be built to a particular airline's specification."[25] After delivery of the first S-40 in 1931, Trippe named the aircraft *American Clipper,* in tribute to the China tea trade clipper ships of the 1860s, the fastest sailing ships of their day.

Dinner Key Terminal. Source: Historic American Buildings Survey, ca. 1934

In November 1931, with three S-40 flying boats, Trippe inaugurated extensive international mail and passenger services to the Caribbean and then to South America. The longer-range S-42 began passenger service in South America in August 1934 from the Pan Am International Airport, at its Dinner Key base in Miami, Florida [Pan American Seaplane Base and Terminal Building, NR, 1975].[26] Built in 1933, this terminal building has been documented as part of the

[24] Ibid. Charles Lindbergh referred to the S-38 as the "flying forest" because of its series of struts and bracing wires supporting the engines and wings. Allward, *Illustrated History,* 81. Trippe, Lindbergh, and their wives flew an earlier Sikorsky eight-seat S-38 flying boat on "an island-hopping flight across the Caribbean and around Central America" to equate an image of flying boats with glamour. Grant, *Flight*, 158-59.
[25] Gandt, *China Clipper,* 60.
[26] Grant, *Flight,* 159.

Historic American Buildings Survey collection. The documentation describes Dinner Key as "the largest and most modern marine air terminal in the world:"

> Said to be one of the best planned terminal buildings constructed for either land or marine airports, it was noted for its innovative layout plan for traffic handling and for its scientific design. This design allowed for the simultaneous handling of four airliners, a feature not previously found in air terminals. Often described as the "Air Gateway Between the Americas," Dinner Key was the nation's busiest commercial seaplane terminal.[27]

Charles Lindbergh convinced Trippe that the most efficient route across the Pacific would be to fly along the coast of Alaska and then on to Japan and, finally, on to China. Diplomatic problems with both the Soviet Union and Japan, however, forced Trippe to look at alternative routes. The most obvious way was to go straight across the ocean, from California to Hawaii, and then on to Midway Island and Wake Island, an uninhabited lagoon in the Western Pacific. From there, the planes could fly to Guam and finally to the Philippines. Despite only lukewarm interest from the U.S. postal service for such routes, Trippe pressed ahead with his plans. In 1935, Pan American built flying-boat bases at Midway, Wake, and Guam in what historian R. E. G. Davies describes as probably "the most efficient single programme of preparatory work ever accomplished in starting a new air route."[28]

For the initial flights, Pan American used the 52-passenger Martin M-130 flying boat, a thoroughly modern plane equipped with state-of-the-art navigation systems and a range of 3,200 miles. The interior of the large but graceful aircraft was modeled like a hotel, with broad armchairs and full meal service. Trippe dubbed the first plane the *China Clipper*. On November 22, 1935, CBS and NBC broadcast the airline's first mail service across the Pacific, flying from San Francisco to Hawaii, and then on to Manila in the Philippines by way of Midway, Wake, and Guam.[29]

A year later, in October 1936, Pan American inaugurated its first passenger flights across the Pacific via the transformed islands. Prior to development, Midway had been a "sandspit" with a cable station on a sandbar[30] and Wake Island had been uninhabited. The islands now featured docks with electric lights and pergolas,[31] staff quarters, and hotels where weary passengers could rest from the rigors of flying. A Pan Am Airways brochure described the facilities on Midway and Wake:

> There is a golf course in the sand! Beyond, a dozen buildings—quarters for the staff, a power house, a refrigeration plant and warehouse, the well-kept compound of the cable relay station. Tall Windmills. The substantial-looking V-shaped hotel. A long pier.[32]

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[27] Sarah Eaton, "Pan American Airways System Terminal Building," Historic American Buildings Survey (Washington, DC: Library of Congress, 1981), available at http://memory.loc.gov/ammem/collections/habs_haer/.
[28] For quote, R. E. G. Davies, *Airlines of the United States*, rev. ed. (Washington, DC: Smithsonian Institution Press, 1982), 249.
[29] Gandt, *China Clipper*, 1-2.
[30] Solberg, *Conquest of the Skies*, 230.
[31] Gandt, *China Clipper*, 108.
[32] "Pan Am Clipper," http://users.ev1.net/~gpmoran/PanAmClipper.htm (accessed July 20, 2004, since removed).

> From the cool verandah of the hotel you look across the beautiful lagoon, whose lovely colors change constantly before your eyes.
>
> Down paths lined with magnolia are living quarters of the base staff, the power plant, the big refrigerators, a little hospital, a pergola where you find an unusual collection of the little atoll's lore.[33]

Writing on the age of flying boats, Robert Gandt, a former naval officer and aviator, described the hotels:

> [They were] sprawling, forty-five-room structures, incongruously Georgian in architecture, with white pillars and a plat of grass on each side of a brick walkway. The two wings of the inns spread like giant claws in either direction. While a wild surf crashed against the encircling reef outside, the guests in the hotel were served exotic cuisine by white-uniformed Chamorro stewards. There were Simmons beds in the rooms, bathrooms with hot showers, spacious verandahs, elegant lounges with wicker furniture.[34]

In Guam, which was comparatively well developed, planes landed at Apra Harbor where passengers used a facility rented by the U.S. Navy, which administered the territory. Passengers "sat on shaded verandahs, sipped their drinks, and waited until four o'clock the next morning when their clipper would take off for Manila."[35]

Soon after establishing the service to Hong Kong and Manila, Trippe looked forward to expanding routes in Australia and New Zealand. Although the British refused to grant landing rights to Australia, New Zealand was more cooperative. Pan American's Clippers began flying regular passenger services to New Zealand in March 1937, flying via the Kingman Reef south of Hawaii and American Samoa.

Using the Martin M-130 seaplanes, Pan American Airways became the world's dominant transoceanic airline. On regular flights across the Pacific, the bulk of the cargo was mail, leaving room for eight to ten passengers who could stretch out in three large compartments, and a larger lounge/dining salon. During the 18-to-20-hour trip from San Francisco to Hawaii, passengers could enjoy cocktails in the lounge and formal evening meals. So famous were the Pan American Clipper flying boats that Hollywood even produced a movie titled *China Clipper* starring Humphrey Bogart. An image of glamour accompanied flying boat travel, and junkets such as "flying down to Rio" became chic among wealthy socialites. A trip from San Francisco to Manila cost a staggering $1,400, the average worker's annual salary.[36]

Pan American's ambitious plans for expansion were tragically cut short when two Clippers, the *Samoan Clipper* and the *Hawaii Clipper,* crashed in 1937 and 1938 within six months of each other, killing all on board. With only two remaining Martin flying boats, the company was forced to cut its schedule by 60 percent. Passenger business also dropped off sharply as public confidence in the Clipper service plummeted. At the same time, Pan American's monopolistic

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[33] Ibid., 8, 9, website includes an aerial photo of Wake Island and deplaning dock.
[34] Gandt, *China Clipper*, 108.
[35] Solberg, *Conquest of the Skies*, 230; Gandt, *China Clipper*, 109.
[36] Grant, *Flight,* 162. See also, Rosalie Schwartz, *Flying Down to Rio: Hollywood, Tourists, and Yankee Clippers* (College Station: Texas A&M University Press, 2004).

practices in the international market drew fire from many. Pioneer aircraft builder Grover Loening resigned from Pan American's board over its monopolistic aims. The Department of Commerce subsequently withdrew its authorization for Pan American to use American Samoa as a landing point.

Trippe was determined to salvage the Pacific Clipper service. In a brilliant strategic move, he introduced the magnificent Boeing Model 314 seaplane. The huge whale-shaped aircraft had already proved itself in the North Atlantic, and its range of 3,500 miles was perfect for the Pacific. The B-314's first trial flight across the mid-Atlantic occurred on March 26, 1939. After a well-publicized dedication ceremony, attended by First Lady Eleanor Roosevelt, the Pan American B-314 *Yankee Clipper* flew from Baltimore, Maryland, to Foynes in Ireland. The airline began regular mail services with the B-314 in May 1939; scheduled flight time was about 29 hours. With increased confidence in its new plane, Pan American inaugurated the world's first transatlantic passenger service on June 28, 1939, between New York and Marseilles, France. On July 8, transatlantic passenger service began between New York and Southampton.

By the beginning of World War II, Pan American dominated the international routes to and from the United States. In March 1940, the airline initiated its seaplane service from La Guardia Airport [Marine Air Terminal, NR, 1982] in New York City to Lisbon, Portugal, the most common entry point into Europe at the time. Pan American's last Atlantic flight on its B-314 flying boat occurred in January 1946, and the last Pacific flight occurred four months later. "[T]hese extraordinary aircraft were the biggest airliners to fly until the age of the jumbo jet, and probably the most luxurious fixed-wing passenger aircraft ever built."[37] Although the seaplane service ended, Pan American's legacy of excellent service and adventure, and the extraordinary ambition of its founder, has not been equaled in the postwar era.

1930s and the Modern Airliner

After the seaplane, the next great leap in aircraft came with the modern airliner. Under the 1930 McNary-Watres Act, the Post Office now paid operators according to the amount of space available for mail rather than the actual mail carried. Airlines now purchased larger aircraft and, after loading the mail, filled any open space with passengers to make still more money. Demands for more capable aircraft, usually defined as having longer range and higher payload capacity, led to new technologies which shaped the modern airliner. Airlines had access to the most advanced equipment because the government had prohibited corporate ownership links between airlines and aircraft manufacturers after the airmail cancellations. As a result, aircraft improved more in this period than at any other time since World War I.[38]

An air crash involving a plane operated by Transcontinental and Western Air (TWA) further accelerated the evolution of the modern airliner. In March 1931, a wooden Fokker F-10A crashed in a field near Bazaar, Kansas, killing nine, including famed Notre Dame football coach Knute Rockne.[39] As fate would have it, Postmaster General Brown was preparing to "unlimber his safety speech" during a Chamber of Commerce luncheon in Savannah when an air promoter

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[37] This service gained fame in the 1942 feature film, "Casablanca," where escaping Nazi occupied Europe required taking the Clipper from Lisbon to America. Ibid., 163.
[38] Smith, *Airways*, 311-12.
[39] A memorial to the victims marks the Knute Rockne crash site. "Knute Rockne Crash Site Memorial," http://www.kansasphototour.com/rockne.htm (accessed on July 12, 2004).

whispered to him that the plane had crashed and Rockne was dead. About the speech, Brown later said, "I did not know what to do, so I made my speech as usual.…I did not tell a soul."[40]

The Aeronautics Branch of the Department of Commerce discovered that moisture inside the wing had deteriorated the glue and weakened the strength of the wing.[41] The crash "spelled the end of the wooden commercial plane."[42] TWA contacted Boeing for a replacement plane only to learn that the first 59 of the new 10-passenger Boeing Model 247, then in production, had been sold to United. Introduced in 1933, this revolutionary aircraft cruised at 155 miles per hour, 50 percent faster than the tri-motors. It "was the first air transport plane to reflect the progress made in engines and streamlining in the early 1930s," and it "started the era of the modern airliner."[43]

Unable to buy the B-247, Jack Frye, TWA's vice president for operations, sought a better airliner than the 247. He set out specifications for this new airliner in a letter to the five leading plane manufacturers: Curtiss-Wright, Ford, Martin, Douglas, and Consolidated. Donald Douglas, founder of the Douglas Aircraft Company, responded with the DC-1 (standing for Douglas Commercial). This plane used a twin-engine design, rather than the three engines that Frye specified, as well as powerful engines produced by Pratt & Whitney and Curtiss-Wright. A twin-engine design could both offer a quieter cabin ride and omit the aerodynamic drag caused by an engine located in front of the pilot. Following a successful test flight on one engine, as demanded by TWA, the company placed an order for 25 planes. In the meantime, a new more powerful Wright engine was produced. Rather than building another DC-1, Douglas built the DC-2. Modifying the plane to carry more passengers, the DC-2 "represented an early exercise in cramming in more passenger accommodations so each flight could sell more tickets and make more money." Overall, the revolutionary designs of the B-247 and the DC-2, together with the restructured airway map and the built-in incentives of the McNary-Watres Act, were "responsible for the continued growth in air passenger travel during the first half of the 1930s."[44]

Another airline closely associated with the DC-2 was Eastern. Eddie Rickenbacker, the famed World War I ace, had joined with associates to purchase Eastern wholesale from North American Aviation in 1937. Rickenbacker was responsible for setting up Eastern's Great Silver Fleet, a famous fleet of DC-2 aircraft that operated on the East Coast. One of these planes became the

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[40] Description given by Brown during the congressional hearings on the airmail contracts. Smith, *Airways,* 275, quoting "Testimony of Walter Folger Brown," within 2569-74.

[41] While investigating this highly publicized accident, the Aeronautics Branch of the Department of Commerce repeatedly botched its findings. The crash was the "most sensational air accident that the Aeronautics Branch had to deal with in its brief history." Nick A. Komons, *Bonfire to Beacons: Federal Civil Aviation Policy under the Air Commerce Act, 1926-1938* (Washington, DC: Smithsonian Institution Press, 1989), 188, 183.

[42] Solberg, *Conquest of the Skies,* 244. The standard work on the Boeing 247 is F. Robert van der Linden, *The Boeing 247: The First Modern Airliner* (Seattle: University of Washington Press, 1991).

[43] Heppenheimer, *Turbulent Skies,* 47; Grant, *Flight,* 146, 150; Roger E. Bilstein, *Flight in America: From the Wrights to the Astronauts,* 3rd ed. (Baltimore: Johns Hopkins University Press, 2001), 89. With the 247, United operated 10 round-trips daily between New York and Chicago, making the airline the "undisputed leader of the route." American and TWA operated only one flight per day. Davies, *Airlines of the United States,* 181.

[44] Davies, *Airlines of the United States,* 183-84; Heppenheimer, *Turbulent Skies,* 51, 53; quotes from Bilstein, *Flight in America,* 90; and Komons, *Bonfire to Beacons,* 211 respectively. In the early years of airline history, airlines associated themselves with famous personalities. William John Frye, TWA's first director of operations and the airline's president in 1934, was a former Hollywood stunt flier. Frye "made sure that TWA was at the forefront of modern technological advances, piloting the single DC-1 that Douglas built." Asif Siddiqi, "Trans World Airlines (TWA)."

first commercial airplane to touch down at Washington, D.C.'s new National Airport in June 1941.[45]

The DC-3, the next great contribution in airliners, began as a sleeper version of the DC-2. American Airlines wanted an aircraft that could carry 14 passengers in bunks for a transcontinental route. In response, Douglas produced the Douglas Sleeper Transport (DST), which first flew in December 1935. American Airlines took delivery of the first DST on June 8, 1936, and began scheduled service on its New York–Chicago route 17 days later.[46] Called the *American Eagle* and the *American Arrow*, these services set new standards for coast-to-coast passenger flights with three stops and 16 to 18 hours travel time in good weather.[47] The DST was redesignated the DC-3 in its more well-known "day coach" (nonsleeper) version.

The introduction of the DC-3 by American Airlines marked the beginning of a new era in passenger aviation. The airliner had almost half the operating expenses of others and provided major advances over the B-247. Twice as many passengers could fly from New York to Los Angeles four hours faster on the DC-3 than on the B-247D. American Airlines put its DC-3s into regular service in the spring of 1936 on its New York–Chicago run. In doing so, it became the first airline operation to reach the "holy grail of commercial aviation," a plane that could pay its way on passenger revenue alone.[48] An American Airlines timetable of July 1936 touted the new nonstop service:

> At christening ceremonies in both cities (New York and Chicago) the Flagships were acclaimed by socialites, prominent businessmen, public officials and Naval officers…who were curious to see this new Flagship of the air. The most heart-warming applause came from old time air travelers on the inaugural flights who judged the Flagship to be everything claimed for it by officials of American Airlines and Douglas Aircraft.[49]

Between 1933 and 1937, the company's passenger volume tripled, and in the following five years the numbers increased eleven-fold. By 1939, American Airlines was flying the most passenger miles of any domestic airline, and at least 75 percent of all air travelers were flying on DC-3s.[50] The aircraft was reliable, easy to service, and "considered indestructible."[51] Pilots

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[45] In the 1930s, Eastern acquired a number of companies in order to expand its routes. In April 1938, North American Aviation finally sold Eastern because of criticism that it was unfair for a single company to both produce and operate aircraft as North American did. Asif Siddiqi, "Eastern Airlines," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Commercial_Aviation/EasternAirlines/Tran13.htm (accessed March 5, 2004).

[46] Asif Siddiqi, "American Airlines," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Commercial_Aviation/American/Tran15.htm (accessed March 5, 2004); Davies, *Airlines of the United States*, 190. After introduction of the DC-3, American Airlines used the DST to inaugurate the *American Eagle* skysleeper transcontinental service. Davies, *Airlines of the United States*, 191.

[47] Roger E. Bilstein, electronic communication with Susan Salvatore, National Park Service, November 2004.

[48] Quote, Grant, *Flight*, 147; Bill Yenne, *Classic American Airliners* (St. Paul: MBI Publishing Company, 2001), 8; Bilstein, *Flight in America*, 91.

[49] Davies, *Airlines of the United States*, 191, from July 15, 1936, American Airlines' timetable.

[50] Siddiqi, "American Airlines"; Judy Rumerman, "Commercial Flight in the 1930s," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Commercial_Aviation/passenger_experience/Tran2.htm (accessed March 5, 2004). Another plane produced at the time was the Lockheed Electra. This smaller plane had larger engines and was faster than the DC-3 with a cruising speed of 203 miles per hour. Bilstein, *Flight in America*, 92.

favored the DC-3 for its maneuverability as a craft that "could almost fly by itself" as compared to the DC-2, "'a stiff-legged brute' that was hard to land." The DC-3, according to co-pilot E. K. Gann, "was 'an amiable cow that was forgiving of the most clumsy pilot'."[52] For passengers, soundproofing and upholstered seats reduced the level of noise and vibration experienced on the earlier tri-motors. However, for passengers flying aboard unpressurized airliners of the era, turbulence was still a problem.[53] Gann described the conditions of summer flying:

> The…air is annoyingly potted with a multitude of minor vertical disturbances which sicken the passengers and keep us captives of our seat belts. We sweat in the cockpit, though much of the time we fly with the side windows open. The airplanes smell of hot oil and simmering aluminum, disinfectant, feces, leather, and puke…the stewardesses, short-tempered and reeking of vomit, come forward as often as they can for what is a breath of comparatively fresh air.[54]

Nonetheless, for all its advantages, the DC-3 was "one of the most successful airplanes in aviation history."[55] Airlines using the DC-3 could pursue a policy of bidding low on new mail routes to obtain a nearly exclusive passenger route. "By 1937, passenger traffic was easily producing more revenues than mail carriage, a development that cried out for scrapping a system whereby routes and schedules were fixed to meet the parochial needs of the Post Office, not the traveling public."[56]

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[51] Quotes, Grant, *Flight,* 147-48.
[52] Allen, *Airline Builders,* 133-34.
[53] Rumerman, "Commercial Flight in the 1930s."
[54] Bilstein, *Flight in America,* 92.
[55] Grant, *Flight,* 147.
[56] Komons, *Bonfire to Beacons,* 356.

AIR RACING & RECORD SETTING[57]

During this golden age of aviation, "private aviation," later known as "general aviation," began to play a growing role in America. Reflecting the emphasis on private aviation in the 1920s and 1930s, the public became increasingly enamored of national air races. Although the military had dominated the Pulitzer race from 1920 to 1925, civilian pilots and homebuilt planes tended to excel in the Thompson contest. The Thompson Trophy Race (1929-1939) began when two brothers from California, Clifford and Phillip Henderson, persuaded Thompson Products of Cleveland, Ohio, a manufacturer of automobile and aircraft engine parts, to sponsor the race. Hopkins Airport (now Cleveland Hopkins International Airport) hosted the event annually except in 1933 and 1936 when the race took place at Los Angeles, California [Hangar One, NR, 1992].[58] Like the Pulitzer, the Thompson was a closed-circuit, pylon-marked contest. There was one difference: rather than planes competing one at a time, the Thompson was a horse race in the air as pilots started together and jockeyed for position. As one Thompson racer noted, "It was a toss-up whether everybody was going to get to that first pylon alive." In 1929, Doug Davis piloted a Travel Air Model R *Mystery Ship* to victory, becoming the first civilian aircraft to win in the National Air Races. Commenting on the surprising victory, General William "Billy" Mitchell noted that a light-plane company in Wichita "[built] an airplane for peanuts that…utterly destroy[ed] the best fighters the military had to offer."[59] The configuration of the Model R became the basis for innumerable successful 1930s racers.

The Bendix Trophy Race (1931-1939), started by industrialist Vincent Bendix, was a transcontinental, point-to-point race. This race encouraged engineers to build faster, more reliable and durable aircraft, which in turn had a major influence on the future of commercial aviation. During the 1930s, Bendix competitors annually flew from Burbank, California, to Cleveland, Ohio, except for two years when the contest began at Floyd Bennett Field on Long Island and ended at Mines Field in Los Angeles. The winner of the Bendix Trophy in 1931 was renowned stunt pilot Jimmy Doolittle. A World War I and World War II army aviator as well as an outstanding test pilot, Doolittle was the first person to win all major aviation racing trophies of his day. In 1925, Doolittle won the Schneider Trophy for flying a Curtiss navy racer seaplane the fastest it had ever been flown. In the 1931 Bendix race, Doolittle flew from Burbank, California, to Cleveland, Ohio, establishing a new record with his Laird *Super Solution* racing plane.[60] He also won the 1932 Thompson Race in a privately manufactured plane—one of the infamous 1930s Gee Bee racing planes. Among the fastest of their day, these planes were

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[57] Portions of this section were taken from David H. Onkst, "The Major Trophy Races of the Golden Age of Air Racing," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Explorers_Record_Setters_and_Daredevils/trophies/EX10.htm (accessed February 13, 2004).

[58] S. H. Schmid and Truman C. Weaver, "Air Race Listing," in *The Golden Age of Air Racing* (Oshkosh, WI: EAA Aviation Foundation, 1991), 2. This facility is today officially known as the NASA John H. Glenn Research Center at Lewis Field. Daniel R. Glover, "History of the Lewis Research Center," NASA, http://sulu.grc.nasa.gov/history/whyhere.html (accessed October 12, 2004).

[59] Frank Joseph Rowe and Craig Miner, *Borne on the South Wind: A Century of Kansas Aviation* (Wichita: Wichita Eagle and Beacon Publishing Co., 1994), 120.

[60] Richard P. Hallion, *Legacy of Flight: The Guggenheim Contribution to American Aviation* (Seattle: University of Washington Press, 1977), 123; Dwayne A. Day, "James H. 'Jimmie' Doolittle: Outstanding Man of Aviation," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Explorers_Record_Setters_and_Daredevils/doolittle/EX18.htm (accessed August 12, 2004). Doolittle also became one of the first people to earn a doctorate degree in aeronautical engineering in 1925.

described as "little more than engines with wings attached." They were also regarded "as among the most dangerous aircraft ever built."[61]

Several women excelled in the Bendix. In 1936, Louise Thaden and her co-pilot Blanche Noyes won the Bendix, defeating some of the world's best male pilots. That year, Laura Ingalls, who had been the first woman to make a solo transcontinental flight, finished second. Amelia Earhart placed fifth, giving women three of the top five finishes.[62] Two years later, Jackie Cochran, arguably the greatest female aviator, won the contest. "The 1936 Bendix race," states Tom Crouch, "underscored how women had reached equality with men at the highest level of aeronautical competition."[63]

Power Puff Derby

Before they were allowed to compete alongside male pilots in the 1936 Bendix Trophy race, women pilots competed in their own races. The first Women's Air Derby was a transcontinental race flying from Clover Field in Santa Monica, California, to Cleveland, Ohio. Comedian Will Rogers nicknamed the women's event, part of the 1929 National Air Races, the "Powder Puff Derby." This was the first time that women were invited to race airplanes, and the pilots knew that their success would open jobs in aviation, especially piloting, to women.[64]

The derby inspired a sense of camaraderie among the contestants, and soon after, race winner Louise Thaden, and another contestant Amelia Earhart, co-founded an international organization of women pilots.[65] Following the Women's Air Derby, 26 women pilots met in a hangar at Curtiss Field, Valley Stream, New York, for the first organizational meeting to name their group. Because 99 of the 117 licensed female pilots in the United States had responded favorably to forming an organization, Earhart suggested naming the group after these charter members. With Earhart as the group's first president, the Ninety-Nines sponsored highly visible and popular air races. They also fought to place women in military and commercial aviation as pilots, conducted humanitarian projects such as ferrying medical supplies, created scholarships to encourage women to pursue an education in aviation and engineering, and sponsored pilot safety programs. In 1934, the organization used funds from the Works Progress Administration (WPA) to start the National Air Marking Program that identified airports to pilots. This was the first government program conceived, planned, and directed entirely by women.[66]

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[61] Grant, *Flight*, 129. The Gee Bees, which took their name from their designer, Granville Brothers Aircraft, are among the most controversial airplanes in aviation history. By some, the Gee Bees are considered "killer planes" because several pilots lost their lives while flying them; others admire their engineering and claim that the planes were too aerodynamically advanced for the pilots of the day to handle. David H. Onkst, "The Gee Bees: The Planes, Their Designers, and Their Pilots," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Explorers_Record_Setters_and_Daredevils/Gee_Bees/EX23.htm (accessed August 12, 2004).

[62] In the 1936 race, Col. Roscoe Turner, who had won the trophy in 1933, and Benny Howard, who won in 1935, had withdrawn due to a crash. Joseph J. Corn, *The Winged Gospel: America's Romance with Aviation* (Baltimore: Johns Hopkins University Press, 2002), 71.

[63] For quote only, Tom D. Crouch, *Wings: A History of Aviation from Kites to the Space Age* (New York: W. W. Norton, 2003), 308.

[64] Gene Nora Jessen, "1929 Travelair 4000," The Ninety-Nines, http://www.ninety-nines.org/travelair.html (accessed February 2, 2004).

[65] Pamela Feltus, "The Ninety-Nines," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Explorers_Record_Setters_and_Daredevils/99s/EX21.htm (accessed February 23, 2004).

[66] For more information on the National Air Marking Program, see Ellen Noblis-Harris, "Marking the Way," The Ninety-Nines, Inc., http://www.ninety-nines.org/index.cfm/air_marking.htm.

Amelia Earhart[67]

Ninety-Nines co-founder Amelia Earhart, nicknamed "Lady Lindy" because her achievements were comparable to those of Charles Lindbergh, was the most famous aviatrix of her time and she remains the most celebrated of all women aviators today. In October 1922, Earhart received her pilot's license from the Federation Aeronautique Internationale. That same month, she set a women's altitude record of 14,000 feet in an open-cockpit, single-engine biplane, the Kinner Canary.

Between 1930 and 1935, she set additional records. On July 6, 1930, she set a women's speed record of 181 miles per hour in a Lockheed Vega, and, on April 8, 1931, she set an autogiro (rotary wing aircraft) altitude record of 18,415 feet. In May 1932, Earhart became the first woman to fly solo across the Atlantic Ocean in her Lockheed Vega [Lockheed Vega 5B – Amelia Earhart]. The flight was the second solo flight across the Atlantic and the longest nonstop flight by a woman. A month later, President Herbert Hoover awarded Earhart the National Geographic Society Medal for her achievement. She was also the first woman to receive the congressional Distinguished Flying Cross. She then set the women's nonstop transcontinental speed record, and in August 1932, became the first woman to fly solo coast to coast. In January 1935, Earhart became the first person to make a solo flight over the Pacific Ocean, flying from Honolulu, Hawaii, to Oakland Airport in California. This was also the first flight where a civilian aircraft carried a two-way radio.

On May 21, 1937, Earhart embarked on her quest to become the first person to fly around the world at its widest point, the equator. Earhart and her navigator, Fred Noonan, departed from Oakland Airport and, on June 30, landed at Lae, New Guinea, having traveled 22,000 miles, with 7,000 miles left to go. She never reached her next destination on Howland Island, most likely disappearing somewhere off the coast of the island after running into a storm. Despite this failure, Earhart's accomplishment demonstrated that women could set their own course in aviation and other fields.

Jackie Cochran[68]

During her aviation career, Jackie Cochran received more than 200 awards and trophies and set more speed and altitude records than any of her contemporaries, male or female. From the 1930s until her death in 1980, she made significant contributions to aviation history. Unlike many other famous aviators, Cochran was originally uninterested in learning to fly. She had obtained her pilot's license only so she could sell her own line of cosmetics across the country.

After abandoning two air races because of mechanical difficulties with her aircraft, Cochran's luck changed dramatically in 1937. She finished first in the women's division of the Bendix and third overall. In December of that year, Cochran set a national speed record from New York's

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[67] This section is based on Keri Rumerman, "Amelia Earhart," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Explorers_Record_Setters_and_Daredevils/earhart/EX29.htm (accessed March 19, 2004).

[68] The source for this section is David H. Onkst, "Jacqueline 'Jackie' Cochran," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Explorers_Record_Setters_and_Daredevils/cochran/EX25.htm (accessed March 19, 2004).

Floyd Bennett Field to Miami. She also achieved a new women's national speed record of 203.895 miles per hour. In 1937, Cochran received the Clifford Harmon Trophy for the most outstanding woman pilot. By the end of her career, she would obtain 15 such trophies.

In September 1939, Cochran won the Bendix when she flew a Russian-made Seversky fighter plane between Los Angeles and Cleveland. For this feat, she also earned the William Mitchell Memorial Award, an award given to the person who makes the most outstanding contribution to aviation during a given year. During the following year, she set a new transcontinental west-to-east coast speed record for women, a new women's national altitude record at 30,052 feet, and two new world records for the fastest times over a 1,000- and a 2,000-kilometer course. Her illustrious career would continue in the post-war years.[69]

Howard Hughes

Another racer, Howard R. Hughes, Jr., went on to become one of the world's most important aviation innovators as well as the recipient of many honors.[70] A famous billionaire, industrialist, and filmmaker, Hughes was involved in aviation in multiple capacities. In 1932, Hughes established the Hughes Aircraft Company in Glendale, California. Its mission was to build the best racing planes in the world. Hughes's first design was the H-1 racer, which he piloted to several speed records in the mid-1930s. The plane's innovative features stabilized the airflow, reduced drag, and prevented dangerous movements of the aircraft. Other features made the plane an outstanding example of streamlining. On September 13, 1935, at Martin Field near Santa Ana, California, Hughes piloted the H-1 to a new speed record of 352 miles per hour, beating the previous record of 314 miles per hour.

Hughes then pursued a new transcontinental speed mark. Because the H-1 was originally intended for only short flights at low altitudes, Hughes purchased a new aircraft, a Northrop Gamma, from fellow aviator Jackie Cochran. After refitting the Gamma with a different engine, Hughes took off from Burbank, California, on January 13, 1936, en route to Newark, New Jersey, and a new cross-country record. Within two weeks, he had also set flight records from Miami to New York and from Chicago to Los Angeles. Hughes then redesigned his H-1 to handle long-distance flights at high altitudes. On January 18, 1937, he flew the H-1 from Burbank to Newark two hours faster than his previous record. With this achievement he won the year's Harmon International Trophy, for the world's most outstanding aviator. "The Hughes H-1 was designed for record-setting purposes, but it also had an impact on the design of high-performance aircraft for years to come."[71]

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[69] In 1950, Cochran set a new international speed record for propeller-driven aircraft by flying a P-51 at 447.47 miles per hour. In 1953, in a Sabrejet F-86, she became the first woman to break Mach 1, the sound barrier. In the 1960s, Cochran established many new marks while working as a test pilot for Northrop and Lockheed. In 1961, she established a string of eight major speed records in a Northrop T-38. Three years later, she set three new speed records in a Lockheed 104 jet Starfighter. During one of her runs, she flew more than 1,429 miles per hour, the fastest a woman had ever flown. She also advised the U.S. Air Force, the Federal Aviation Administration, and the National Aeronautics and Space Administration (NASA). Onkst, "Jacqueline 'Jackie' Cochran."

[70] This section is based on Judy Rumerman, "The Hughes Companies," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Aerospace/Hughes/Aero44.htm (accessed March 19, 2004); and David H. Onkst, "Howard R. Hughes, Jr.—The Record Setter," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Explorers_Record_Setters_and_Daredevils/Hughes/EX28.htm (accessed March 19, 2004.

[71] For quoted material, Smithsonian National Air and Space Museum, "Hughes H-1 Racer," http://www.nasm.si.edu/research/aero/Aircraft/Hughes_h1.htm (accessed September 12, 2007).

In 1938, Hughes pursued Wiley Post's around-the-world record in a Lockheed 14, twin-engine, passenger plane powered by two 1,100 Wright Cyclone engines. He had stripped the aircraft's interior to add the latest refinements in aircraft and equipment. The press dubbed his aircraft, with its additional radios and navigational aids, the "Flying Laboratory." Hughes and his four-man crew departed Floyd Bennett Field on July 10, 1938, and made Paris in less than half Charles Lindbergh's 1927 time. On July 14, he landed in New York in front of 25,000 cheering people. His new record shaved more than four days off Post's previous record and garnered him several honors including a Congressional Medal and a second Harmon International Trophy.

The transglobal flight marked the end of Hughes's record-setting days and "gilded the achievements of long-distance fliers before him. The faultless flight had been ahead of its time. It was a dramatic demonstration of the technical advances that had been made in aviation. In particular, Hughes's meticulous provision and use of radio navigation aids and weather forecasts were ahead of the systems then in use. He had signposted the way for the future."[72]

The Decline of Air Racing

At the close of the 1930s, the high number of lives lost led people to question the benefits of air racing. Although some of the innovations developed for air racing were integrated into the designs of many contemporary civil and commercial aircraft, many advances only benefited racing aircraft that were designed to fly short distances at low altitude.[73] Trophy winner Jimmy Doolittle argued that air racing had "outlived its usefulness."[74] In October 1934, the *Aero Digest* confronted the Department of Commerce over air racing's high fatality rate and the need for new licensing regulations to "insure that these high speed races shall serve to advance the science of aviation and shall not be degraded into a Roman holiday for the sadistic entertainment of morons." Over fifteen years, design innovations spurred by air racing had only led to a net gain in speed of 34 mph. Noting that more than one-third of the Bendix and Thompson champions had been killed in air racing, Gwynn-Jones maintained that this limited gain in air speed "was a paltry prize in terms of time, effort, and the lives it cost."[75] Racing's popularity also declined in the years preceding World War II as the public turned its attention elsewhere.

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[72] Gwynn-Jones, *Farther and Faster*, 270-71, 273. Hughes's most famous aircraft was the Hughes Flying Boat H-4 [NR de-designated], named the "Spruce Goose." It had originated as an urgent U.S. government project in 1942 for a fleet of wooden flying transports that would not require critical wartime materials. Delays ensued and by 1944 the flying boat had lost all priority. Hughes persevered and the largest airplane of all time made its only flight on November 2, 1947, rising 70 feet for a mile over California's Long Beach harbor. John T. Greenwood, ed., *Milestones of Aviation: Smithsonian Institution National Air and Space Museum* (New York: Hugh Lauter Levin Associates, 1995), 188. In subsequent years, Hughes concentrated on designing and manufacturing military aircraft and exercising control of Trans World Airlines as its principal stockholder. Hughes, who had survived four plane crashes while testing his own aircraft during his career, ironically died as a passenger on a jet plane on April 5, 1976.

[73] Onkst, "Major Trophy Races"; Grant, *Flight*, 128, 129.

[74] Lowell Thomas and Edward Jablonski, *Doolittle: A Biography* (Garden City, NY: Doubleday, 1976), 128.

[75] Gwynn-Jones, *Farther and Faster*, 172, 176-77.

THE EVERYMAN'S AIRCRAFT

Advocates of the winged gospel believed that flying and owning an airplane would become as commonplace and affordable as the automobile. Eugene Luther Vidal wanted to make this dream a reality. On October 1, 1933, this former World War I pilot and airline executive became the director of the Bureau of Air Commerce within the U.S. Department of Commerce, the agency that regulated and promoted civil aeronautics. Vidal's "New Deal for Aeronautics" initiated a program to produce an affordable "airplane for every man." In the midst of the Depression, Vidal wanted to bring prosperity to the industry through increased employment and sales. "[T]he bureau's attempts to guide aircraft manufacturers onto unfamiliar paths," writes Tom Crouch, "would have important implications for the aviation industry and help shape the public vision of the future of the airplane."[76]

Under the New Deal's Public Works Administration, Vidal was promised $500,000 which he hoped to use in collaboration with the aviation industry to design and manufacture an affordable, all-metal monoplane. Vidal envisioned that this "everyman's aircraft" could be purchased for $700, about the price of a Pontiac automobile, and $300 to $500 less than any plane on the market. To make this dream a reality, Congress amended the Air Commerce Act of 1926 to give the Department of Commerce authority to "participate in such research and development work as tends to create improved aircraft, aircraft power plant, and accessories."[77]

Vidal's plan immediately ran into problems. First, manufacturers of small planes greeted the plan "with a shower of dead cats and brickbats."[78] They referred to the all-metal airplane as the "all mental" airplane, and believed the proposal was an unrealistic fantasy that would only destroy the sales of existing aircraft.[79] Second, President Roosevelt rescinded his approval of the grant following the 1934 airmail scandal that created congressional distrust of the aviation industry. Undaunted, the bureau continued its pursuit of a safer, easier-to-fly aircraft, deciding instead to purchase light airplanes for use by bureau inspectors. The successful bidder would receive a contract for 25 airplanes and the prospect of selling thousands more.[80] The bureau issued specifications for an all-metal, two-seater aircraft with dual controls, a maximum speed of 110 miles per hour, and a maximum range of 300 miles. It had to be easy to control and designed to minimize the danger of spinning and stalling.[81]

To develop its specifications, the Bureau of Air Commerce officials conferred with engineers at the National Advisory Committee on Aeronautics (NACA) Research Laboratory in Langley, Virginia. There Fred Weick, a senior engineer, and his fellow engineers were nearing completion on an aircraft that had caught the bureau's attention. A single engine made operation of the aircraft economical, and its innovative tricycle landing gear was intended to prevent nose-over landing accidents. During a test flight in September 1934, the engine failed and the W-1

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[76] Tom D. Crouch, "An Airplane for Everyman," in *Innovation and the Development of Flight*, ed. Roger D. Launius (College Station: Texas A&M University Press, 1999), 167-168. Vidal envisioned an airplane selling between $700 and $1,000, "although the idea was consistently referred to as the '$700 airplane'." Bilstein, *Flight in America*, 109.
[77] For quote, Crouch "An Airplane for Everyman," 171.
[78] As reported in the periodical, *Aviation*, and quoted in Crouch, "An Airplane for Everyman," 173.
[79] Joseph J. Corn, "The Winged Gospel," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Social/winged_gospel.SH2.htm (accessed September 1, 2004).
[80] Crouch, "An Airplane for Everyman," 175, 176.
[81] Janet R. Bednarek with Michael H. Bednarek, *Dreams of Flight: General Aviation in the United States* (College Station: Texas A&M University Press, 2003), 32.

was damaged in a hard landing. The bureau then funded the aircraft's reconstruction, producing the W-1A. Although a safe airplane, the W-1A was not entered in the competition, "primarily because of its experimental nature, fabric construction, and the fact that no plans had been made to produce the craft for sale."[82]

In 1936, the program came to a close with mixed results. The growth of a mass market for light aircraft had never materialized. Commerce officials had, however, succeeded in bringing attention to the specific needs of the private pilot. In addition, the tricycle landing gear with steerable nose wheel developed during the program was adapted to military and commercial aircraft. Assessing the overall results of the program, Tom Crouch writes, "The Department of Commerce's $700 airplane and competitive purchase programs had little impact on the general-aviation industry, which continued to produce the standard types on the market by 1935. By encouraging experimentation and publicizing new aircraft types, however, Vidal's plans had helped to shape the general public's view of the future of aeronautics, for better or worse."[83]

The W-1A evolved into a refined model called the ERCO 310. ERCO stood for the Engineering and Research Corporation (ERCO) in Riverdale, Maryland. Weick had gone to work there in 1936. The ERCO 310 made its first flight in October 1937 at the College Park Airport in Maryland. Construction of the production prototype was completed in 1939, and the aircraft received certification from the Civil Aeronautics Administration (CAA) in 1940. The Ercoupe was the first modern general aviation airplane. Easy to fly, the aircraft had no dangerous stall characteristics. A placard on the instrument panel proudly announced: "This aircraft characteristically incapable of spinning."[84]

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[82] Quote, Crouch, "An Airplane for Everyman," 176-80. The winner of the competition was the Hammond Model Y manufactured by the Hammond Aircraft Corporation of Ypsilanti, Michigan. Three other planes the bureau purchased included the Waterman Arrowplane (a roadable airplane), a roadable autogiro built by the Autogiro Company of America, and the Curtiss-Wright Coupe. Ibid., 179-80.

[83] Ibid., 180; quote, Crouch, *Wings*, 304. A number of early aircraft had included three landing wheels and "Weick's reintroduction of the tricycle concept was a key innovation." Crouch, "An Airplane for Everyman," 177.

[84] William H. Longyard, *Who's Who in Aviation History: 500 Biographies* (Shrewsbury, UK: Airlife, 1994), 195; quote in Roger Guillemette, "ERCO Ercoupe," U.S. Centennial of Flight Commission http://www.centennialofflight.gov/essay/GENERAL_AVIATION/ERCO/GA12.htm (accessed July 2, 2004).

AIR TRAFFIC CONTROL

Air-Route Traffic Control Centers

In 1934, the Bureau of Air Commerce (formerly the Aeronautics Branch of the Department of Commerce) encouraged four airlines (American, TWA, United, and Eastern) to establish the first three centers for providing air traffic control (ATC) beyond the airport areas to the airways. In December 1935, the first air-route traffic control center (ARTCC) was established at the Newark Metropolitan Airport [NR, 1980], followed soon after by centers in Cleveland and Chicago. The Bureau took over the three ARTCCs in 1936, and expanded the system to Detroit, Pittsburgh, Los Angeles, Washington, D.C., and Oakland by the spring of 1937.[85] These facilities informed airline pilots on the location of other planes in the vicinity when environmental conditions necessitated instrument flying. Each ARTCC was responsible for guiding a plane through its territory and handing it off to another center or to an airport controller.[86]

Early controllers tracked planes using maps, blackboards, mental calculations, and note cards anchored by small weights dubbed "shrimp boats." As a pilot called in his position, a controller moved the shrimp boat along an airway map to approximate the aircraft's position. Since ground personnel could not communicate directly with pilots, they relied on airway radio station operators, airline dispatchers, and airport traffic controllers, all of whom fed information to the controllers en route relaying instructions to pilots. This system initially operated through private telephone lines and weather teletype circuits. When these became too busy, a special teletype circuit was established for air traffic use in 1937. During 1938, the Department of Commerce established teletype network Schedule B, with 10,000 miles of circuits and connected airway traffic control centers, airway communication stations, and military bases. The Schedule B network permitted teletype transmission of flight data independently of weather data transmitted on Schedule A circuits.[87]

In late spring 1939, the Civil Aeronautics Authority (CAA), the independent agency which had taken over federal civil aviation responsibility from the Bureau of Air Commerce in 1938, completed a $7 million airways modernization and improvement program. The Federal Airways System now covered 25,500 miles and was served by 231 radio range stations. By the fall of 1939, the CAA commissioned additional air-route traffic control centers in Fort Worth, Salt Lake City, St. Louis, and Atlanta. In 1940, President Roosevelt split the CAA in half. A new Civil Aeronautics Board (CAB) functioned independently of the Secretary of Commerce, and was entrusted with safety rule making, accident investigation, and economic regulation of the airlines. The new Civil Aeronautics Administration (CAA) was responsible for air traffic control, safety programs, and airway development.[88]

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[85] Federal Aviation Administration, "FAA Historical Chronology, 1926-1996," http://www.faa.gov/about/media/b-chron.pdf (accessed June 2, 2005).
[86] Bilstein, *Flight in America*, 287.
[87] U.S. Centennial of Flight Commission, "Air Traffic Control," http://www.centennialofflight.gov/essay/Government_Role/Air_traffic_control/POL15.htm (accessed June 16,2005); Federal Aviation Administration, "FAA Historical Chronology."
[88] Both the CAA and the CAB created in 1940 were part of the Department of Commerce. Federal Aviation Administration, "History," http://www.faa.gov/about/history/brief%5Fhistory/#3 (accessed April 23, 2008).

Radar

Radar, a form of one-way communication, gathers information on the position of objects that are either far away or hidden by clouds or darkness. Some historians view radar as "the weapon that won World War II and the invention that changed the world." Before and during the war, government secrecy surrounded radar development and even the word "radar" was classified. Because many scientists began working on radar in different places at roughly the same time, historians disagree over who deserves credit for inventing radar.[89]

In the United States, radar development took place at military and academic facilities. In 1934, researchers at the Naval Research Laboratory (NRL) in Washington, D.C., realized that ships traveling on the Potomac River interfered with radio signals being transmitted across the river. They began work on bouncing radio signals off objects and developing an air- and surface-warning radar for ships. Researchers at the Army Signal Corps Laboratory at Fort Monmouth, New Jersey [Camp Evans Historic District, NR, 2002], who understood that airplanes in flight could interfere with the transmission and reception of radio signals, began work on a gun-laying or searchlight-directing radar for antiaircraft artillery.[90] Camp Evans, where the laboratory was located, functioned as the nerve center of the army's wartime radar research and development. The laboratory used and coordinated the work of private contractors, such as Bell Labs in New Jersey, Westinghouse in Maryland, and Western Electric in Illinois, and academic laboratories, such as the Radiation Laboratory ("Rad Lab") at the Massachusetts Institute of Technology, to develop an early warning radar system.

The Rad Lab was established in 1940 as an independent laboratory staffed by civilian and academic scientists from several disciplines. Funding for the laboratory's first year of operation came from financier, philanthropist, and amateur physicist Alfred Lee Loomis, who had also established and operated the highly regarded A. L. Loomis Laboratory in Tuxedo Park, New York [NR, 1980], from 1926 to 1940.[91] The Rad Lab developed microwave radar systems for various uses during the war. These included radar for aiming antiaircraft guns, general search radars for detecting airplanes, shipborne radar, and airborne radars to be carried aboard aircraft and used for a variety of purposes, such as targeting other airplanes, meteorology, and navigation. "The 'RadLab' designed almost half the radar deployed in World War II, created over 100 different radar systems, and constructed $1.5 billion dollars worth of radar."[92]

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[89] Germans, French, British, and Americans all used radar both to guide their ships and airplanes, and to detect enemy craft. Dwayne A. Day, "Radar," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Evolution_of_Technology/radar/Tech39.htm (accessed June 20, 2005).

[90] Louis Brown, "Paths for Flight: Innovation and the Development of Radar," in *Innovation and the Development of Flight*, ed. Roger D. Launius (College Station: Texas A&M University Press, 1999), 194.

[91] Scholars consider the Radiation Laboratory at the Massachusetts Institute of Technology (MIT) to be a principal facility for the development of radar. Radar research was conducted at the Loomis Laboratory before the war, and Loomis met here with the Tizard Mission that brought critical British microwave radar technology to the United States. Members of the Tizard Mission also exchanged information with the U.S. Army and U.S. Navy, and viewed demonstrations of American radar equipment, at the Naval Research Laboratory in Washington, D.C., and the Signal Corps Laboratory at Fort Monmouth, New Jersey. Many of the Loomis staff relocated from New York to the newly opened lab at MIT to participate in the accelerated wartime research and development of radar. See IEEE History Center, Frank D. Lewis interview, June 12, 1991, http://www.ieee.org/organizations/history_center/oral_histories/transcripts/lewis.html, and Dr. E. G. Bowen, "The Tizard Mission to the U.S. and Canada," Radar World, http://www.radarworld.org/tizard.html (accessed June 28, 2005).

[92] Day, "Radar"; Massachusetts Institute of Technology, Research Laboratory of Electronics, "History," http:www.rle.mit.edu/about/about_history.html (accessed June 20, 2005); IEEE Virtual Museum, "MIT's Rad Lab,"

AIRPORTS

A Fading Enthusiasm

Throughout the 1920s airport boosters had emphasized the simplicity and low cost of airport construction. But by the early 1930s, it was clear that airport construction was neither low cost nor simple. The technological advances that allowed for day and night, all-weather flying required better airport lighting systems and prepared or hard-surfaced runways. Because air travel was still the domain of business people and the affluent, better terminal facilities and more airport amenities such as restaurants and comfortable waiting rooms were needed. Airports built in 1928 were often considered obsolete by 1930. Funding also remained a problem as airports seldom generated enough revenue to handle routine upkeep, let alone the improvements demanded.

Before the widespread adoption of the airborne direction finder, known as the A/N system developed by the Bureau of Standards, most aerial navigation depended on visual clues. Lighted airways developed by the Post Office and, after 1926, expanded by the Department of Commerce, ended at airport boundaries. Airports along the lighted airways had to provide night lighting equipment such as floodlights (for illuminating landing areas) and boundary lights. And the airports footed the bill for the electricity. A 1930 Harvard study indicated that on average airports spent $16,935.58 on lighting.[93]

Private sector organizations also contributed to the technological advances. The Daniel Guggenheim Fund for the Promotion of Aeronautics, for example, developed different technologies needed for all-weather or "blind" flying. Operating a flight research center from 1926 to 1929 at Mitchel Field in New York, the fund sponsored the research and testing of a visual indicator for the landing area marker beacon, a precision barometric altimeter, and the Sperry artificial horizon and direction finder. Flying the fund's Consolidated NY-2, on September 23, 1929, military test pilot James "Jimmy" Doolittle conducted the first completely blind flight, a major step forward in air safety.[94]

As aircraft became larger and heavier and as airlines began to fly under more severe weather conditions, paved runways became another new expense. To handle flights under rainy or snowy conditions, airports needed more durable and easily maintained landing surfaces. A number of airports had experimented with runway preparations in the late 1920s and early 1930s using cinder, gravel and asphalt. The Ford Airport near Detroit, Michigan, set the standard, however, when, in 1929, it installed a 75-foot-wide, 2,500-foot-long concrete runway.[95]

Improvements cost money and by the early 1930s it was clear that airports had problems generating revenue. In 1930 and 1931, aviation journals published a number of articles suggesting how airports might make a profit. While their audience included public airport managers, most of the examples came from private airports. For example, Fairfax Airport in

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http://www.ieee-virtual-museum.org/collection/event.php?taid=&id=3456978&lid=19 (accessed June 23, 2005).

[93] Komons, *Bonfires to Beacons*, 144; Henry V. Hubbard et al., *Airports: Their Location, Administration, and Legal Basis* (Cambridge: Harvard University Press, 1930), 90-93. See Chapter 8 for a discussion of the A/N system.

[94] Hallion, *Legacy of Flight*, 111-24.

[95] "Henry Ford's Concrete Airport Runway Dedicated," *U.S. Air Services* 14 (April 1929): 92; American Public Works Association, *History of Public Works*, 211.

Kansas City, Kansas, had enjoyed 20 consecutive profitable months by June 1930. Owned by a local engineering firm, the airport generated revenue through hangar rentals, fuel sales, and lease agreements with flight schools and aircraft manufacturers. The article noted that other airports might do the same. It went on to point out, however, that Fairfax Airport had a particular advantage, as natural gas was discovered on the site. The owners could sell the gas to the manufacturing plants on the airport as well as those in an adjacent industrial district. The author insisted, though, that the airport earned the bulk of its profits from more conventional sources, praising the owners for having "adopted or [planning] to adopt almost every known means for increasing the income of the aviation field," including the use of pay toilets in the administration building, a venture that brought in $2,400 annually.[96]

Another private airport highlighted for its ability to earn profits was Grand Central Airport in Glendale, California. The author of an article about that facility praised the airport manager, Maj. C. C. Mosely, crediting him with "a rare type of business mind and a peculiar ability for devising effective showmanship angles." The airports "joy-hop" service catered to more than 5,000 passengers per month and its Sunday programs included "music, news broadcasts, flying model demonstrations, crop-dusting demonstrations, parachute jumps and demonstrations of airport lights."[97]

Despite these efforts, even the nation's largest airports had problems generating revenue as was made clear in an article by Preston Sneed, director of Dallas's Love Field. By 1931, Love Field was challenging Chicago's airport for second place among the nation's busiest airports. Still, it failed to make money. Sneed noted that the city did not operate the fuel or oil concessions and only owned and leased out two World War I–era hangars. As a result, the airport had cost the taxpayers of Dallas $25,000 in the fiscal year ending July 1931. The city, though, hoped to close the revenue gap during the following year by imposing a number of fees.[98]

Fading enthusiasm for airport construction and worsening economic conditions led many aviation boosters to look beyond the local level for support. After 1933, as part of Franklin D. Roosevelt's New Deal, the federal government would provide the much needed assistance.

A New Deal for Airports

The first federal funding for airports came in the form of work relief under the Federal Emergency Relief Act (FERA) and the Civil Works Administration (CWA). These funds came with certain conditions attached, however. Cities receiving funds had to own or lease their airports; funds could not be used to improve private airports serving as the airmail airport. Before the 1930s, many cities had leased their airports or had them provided by private interests. Although many cities met the ownership requirement and welcomed the aid, many also criticized the link between work relief and airport funding and began to argue for direct aid.

The 1930s witnessed another important change in federal aviation regulation when Congress passed the Civil Aeronautics Act in 1938. For airport development, the new law was important in two ways. First, it removed the ban on direct federal aid to airports imposed by the Air Commerce Act. Second, it vested regulation in the new, central Civil Aeronautics Authority

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[96] James B. Wines, "The Airport on a Paying Basis," *Aviation* 28 (June 21, 1930): 1217-18.
[97] Richard Lincoln West, "Making Airports Pay," *Airway Age* 11 (September 1930): 1211-12.
[98] Preston Sneed, "The Problem of Revenues at a Municipal Airport," *Southern Aviation* 2 (July 1931): 10-12.

(CAA). The law also restructured the airmail subsidy. Under the new system, the CAA and the airlines had more flexibility in determining which airport would be the center of operations, taking into account airline and passenger considerations, rather than the interests of the Post Office.[99]

New Deal Relief Programs

Once President Roosevelt created the CWA in late 1933, Eugene Vidal, the director of aeronautics in the Department of Commerce, announced a $10-million airport improvement program helping approximately 2,000 communities across the nation. Because the CWA was a work relief program, $8 of the $10 million was for wages, and $2 million for materials. Further, Vidal focused primarily on the nation's smaller communities. By late 1934, work was underway at 808 landing fields and airports, with 1,400 projects having received approval. Of the approved projects, 461 were in cities with populations under 5,000. Each project, at least initially, was relatively modest in scope, costing about $5,000 on average. Of that $5,000, most went to wages with only $630 spent on materials.[100]

In 1935, Congress replaced the earlier temporary work relief programs with the more "permanent" Works Progress Administration (WPA). This new agency continued much of the work carried out by the CWA and the FERA, including an expanded airport and airways improvement program. The emphasis, though, remained on work relief and that soon became a source of criticism. In addition to that problem, the ownership requirement forced many cities to purchase their previously leased or private airports. Los Angeles, for example, had applied for aid under the original FERA program, which had approved funding. Once the WPA replaced FERA, however, the WPA turned down the request because the city leased rather than owned its airport. Though the city initially hesitated, in September 1937 it purchased Mines Field in order to benefit from federal airport improvement aid.[101] Dayton civic leaders acted even more quickly. Once they realized that the city would not take independent action, a group led by local newspaper publisher James Cox raised private funds to purchase the airport. They then presented the airport as a gift to the city in April 1936. The city accepted ownership and WPA funding soon followed.[102]

The stricter guidelines and stronger regulation that came with the WPA and the CAA, respectively, often put cities and the federal government at odds over airport improvement projects. A protracted battle ensued, for example, between the WPA, the CAA, and the city of Philadelphia. In 1937, the city sought WPA funds for what became the S. Davis Wilson Airport. Construction was underway when, following a recommendation by the new CAA, the WPA withdrew funding in December 1938. The issue was the alignment of the No. 1 runway. The

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[99] For a more detailed discussion of the Civil Aeronautics Acts of 1938, see Clinton M. Hester, "The Civil Aeronautics Act of 1938," *Journal of Air Law* 9 (July 1938): 451-59; Robert J. Prichard, "The Civil Aeronautics Act," *Western Flying* 18 (July 1938): 14-15.

[100] "PWA to Finance 2,000 New Aircraft Landing Fields throughout the United States," *American City* 49 (January 1934): 72; "Airport Construction Under the CWA Program," *American City* 49 (August 1934): 9.

[101] Paul D. Friedman, "Birth of an Airport: From Mines Field to Los Angeles International, L.A. Celebrates the 50th Anniversary of Its Airport," *Journal of the American Aviation Historical Society* 23 (Winter 1978): 291; "What about the Los Angeles Airport?" *Western Flying* 18 (November 1938): 18.

[102] Janet R. Daly Bednarek and Michael H. Bednarek, "False Beacon: Regional Planning and the Location of Dayton's Municipal Airport," *Ohio History* 106 (Summer/Autumn 1997): 133-38; George F. Baker, "Dayton Improves Its Municipal Airport," *Aero Digest* 29 (December 1936): 28-29.

new runway, with its state-of-the-art blind landing equipment, was directly in line with an ammunition depot at adjacent Fort Mifflin. Both the navy and the CAA, citing safety concerns, asked that the city change the alignment of the new runway. The mayor, S. Davis Wilson, refused and announced the city would complete construction of the airport without WPA funds. The CAA countered by declaring that unless the safety concerns were addressed, it would not certify the airport for passenger traffic. Charges and counter charges flew over the next months until finally, in August 1939, the city, the navy, the WPA and the CAA reached a compromise. The runway remained in place, the ammunition depot was moved, and the CAA agreed to allow passenger airlines to use the airport.[103]

Modern Airports: New York and Washington

Federal funding and regulations also shaped the airport battle that pitted New York City against Newark, New Jersey, and ultimately resulted in the construction of what some call the first modern airport: LaGuardia [Marine Air Terminal, NR, 1982]. The saga began in 1927 when then–Secretary of Commerce Herbert Hoover headed a commission to investigate potential sites for a publicly owned New York City airport. The commission identified ten potential sites in the New York metropolitan region: six for primary airports, four for secondary airports. The following year, the city of Newark, location of one of the proposed primary airport sites, began construction on a municipal airport. It opened in October 1928 as the airmail airport for the New York metropolitan region.[104]

New York City responded by beginning construction on its own public airport on a site also identified by the Hoover Commission. Floyd Bennett Field, located on Jamaica Bay in Brooklyn, opened in 1931. New York City officials then petitioned the Post Office to move airmail operations from Newark Airport to Floyd Bennett Field. For the most part, these officials had simply assumed that the Post Office would respond positively to their request. But the Post Office balked at the cost of the move, arguing that the facility in Newark was actually closer, in terms of travel time, to the main Post office in Manhattan. The campaign to move the airmail to Floyd Bennett Field continued and became particularly energetic under the leadership of Fiorello H. LaGuardia, who was elected mayor of New York City in 1933. Despite LaGuardia's best efforts, Postmaster General James Farley issued a final decree in 1935: airmail operations would remain at Newark.[105]

Newark successfully held off the challenge from New York City as long as the Post Office determined which airport would serve as the airmail airport. However, responsibility for

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[103] Philadelphia Business Progress Association, "A Plan for the Development of the Philadelphia Terminal-Air-Marine-Rail," September 6, 1929, Smithsonian National Air and Space Museum Technical Files, Air Transport Series, Airports, Pennsylvania, Philadelphia. Record Group 69, National Archives, Washington, DC [hereafter WPA Newspaper File].

[104] Porter R. Blakemore and Ana C. Linck, *Historic Structures Report, Historical Data Section, Archeological Date Section, Floyd Bennett Field, Gateway National Recreation Area,* U.S. Department of the Interior, National Park Service, Denver Service Center, Mid-Atlantic/North Atlantic Team, Branch of Historic Preservation, vol. 1 (Denver: n.d.), 4-5; John C. Holme, Jr., "Surveying the Airport Problem in New York City, Part I," *Aviation* 28 (January 11, 1930): 56-58.

[105] Blakemore and Linck, *Historic Structures Report,* 5, 9-10, 33-34, 36-37, 38-40, 43-44; John C. Holme, Jr., "Surveying the Airport Problem in New York City, Part II," *Aviation* 28 (January 25, 1930): 158; "News from the Port of New York Authority" press release, October 1, 1968, 3-4, Smithsonian National Air and Space Museum Technical Files, Air Transport Series, Airports, U.S., New Jersey, Newark; "New York City Dedicates Its Airport," *Aviation* 30 (June 1931): 343.

determining who would fly the mail shifted from the Post Office to the CAA in 1938. With the DC-3 passenger plane in service, the needs of the airlines and its passengers, rather than those of the Post Office, shaped decisions over which airports would have airmail and, thus, airline service.[106]

Poster promoting New York's municipal airports, 1936 or 1937. Source: Library of Congress, Work Projects Administration Poster Collection LC-USZC4-4242

Even as New York City continued the fight to move the airmail to Floyd Bennett Field, Mayor LaGuardia announced plans for another New York City airport. The proposed site was the former Glenn Curtiss Airport, located in Queens and known in the 1930s as North Beach Airport. By late 1935, New York City officials had requested $2.5 million from the WPA to begin improvements. Though the city had no guarantee that the new airport would be more successful than the old airport in garnering the airmail flights, by the time the new airport opened in 1939, the rules had changed. Though Newark's mayor, Meyer Ellenstein, carried on a determined campaign of his own to prevent his city's airport from losing airmail and airline service, his efforts to paint the new New York facility as unsafe and inconvenient were unconvincing. As Lt. Col. Brehon S. Somervell, the WPA administrator in New York City noted in a reply to Ellenstein's charges: "It is a physical certainty that North Beach will be the finest airport in the United States and, so far as I know, in the world.…[i]t will far surpass any metropolitan airport in the country." The new airport had cost an estimated $21 million, with $13.4 coming from federal sources and $7.8 million from the city.[107]

North Beach Airport (soon renamed LaGuardia Airport) opened in October 1939. Eastern Airlines initially objected to a move to the new airport, but after three other airlines (American, TWA, and United) agreed to move their operations to North Beach, Eastern announced that it would do so as well. The CAA approved the new agreements with New York City in late September 1939, allowing the airlines to shift their operations as soon as the new airport opened. This major victory for New York City was a major defeat for Newark. Without airline service, the Newark airport closed in May 1940. It briefly reopened as a civilian airport the following

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[106] Ellis H. Hawley, *The New Deal and the Problem of Monopoly: A Study in Economic Ambivalence* (Princeton: Princeton University Press, 1969), 240-44; Richard H. K. Vietor, *Contrived Competition: Regulation and Deregulation in America* (Cambridge: Belknap Press of Harvard University Press, 1994), 24-30; Smith, *Airways*, 306; Komons, *Bonfires to Beacons*, 355-56, 378-79.

[107] "2,500,000 Asked for North Beach Plan Terminal," *North Shore Journal*, August 3, 1936; "City Pushes Bid to Sea Air Line," *Newark Evening News*, August 19, 1936; "New York as an Air Terminal," *New York Times*, August 28, 1936; "Replies to Ellenstein," *New York Times*, September 29, 1938, all in Box 85, New Jersey, Records of the Work Projects Administration, Record Group 69, National Archives, Washington, DC [hereafter, WPA Newspaper Files].

year, but during World War II the U.S. Army Air Forces took over the facilities. The opening of LaGuardia also spelled the end for Floyd Bennett Field. The city agreed to lease the facility to the navy in 1941 and in February 1942, the navy purchased it outright and operated it as New York Naval Air Station, Floyd Bennett Field.[108]

Though LaGuardia is considered the first modern airport, soon after it began operations, another airport opened to wide acclaim. Also regarded as a model of modern airports, Washington's National Airport represented the most extensive federal involvement in airport construction before World War II. Until 1941, a small, private airport served the nation's capital. In 1926, Hoover Field opened on the banks of the Potomac River across from the District of Columbia. It was soon joined by another small airport, literally across the street (Military Road). Each operated separately until 1930 when they merged to form Washington-Hoover Airport. The combined airport covered 143 acres near the present site of the Pentagon. Military Road still bisected the property and special traffic signals had to be used to stop vehicular traffic so that airplanes could use the longer, combined runway. Though many bemoaned the sad shape of the airport serving the nation's capital, it took many years before construction could begin on a new, more suitable facility.[109]

Although Congress received great pressure from organizations such as the National Aeronautic Association and from individuals such as Charles Lindbergh, the provision in the Air Commerce Act of 1926 that forbade direct federal involvement in the construction of airports prevented action. With the passage of the Civil Aeronautics Act, however, that prohibition was lifted. President Franklin Roosevelt approached the CAA for help in locating and constructing a new Washington airport. At the time, two proposed sites had emerged: Gravely Point, near Washington-Hoover along the banks of the Potomac, and Camp Springs, Maryland. Though Roosevelt favored the Camp Springs site, the CAA decided on Gravely Point. The Public Works Administration (PWA), WPA, and Army Corps of Engineers then took joint responsibility for construction. In 1938 much of the site was underwater, requiring a massive Corp of Engineers filling operation. After the Corps moved approximately 20 million cubic yards of sand and gravel, construction began on the airport's four runways. Plans also included a 115,000-square-foot terminal building, described as "a pleasing blend of the modern with the colonial atmosphere which surrounds the country." Though some controversy remained, the airport opened on June 6, 1941.[110]

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[108] "Leases Signed by 3 Airlines at North Beach," *New York Herald Tribune,* November 17, 1938; "Airlines' Experts Back North Beach," *New York Times*, September 13, 1939; "Third Airline Assures Newark of Full Service, *New York Herald Tribune,* September 14, 1939; "Newark Favored by Rickenbacker," *New York Times,* September 22, 1939; "Newark Airport Failure Feared if Lines Move," *New York Herald Tribune,* September 20, 1939; "Newark Plans Court Appeal of Airport Ruling," *New York Herald Tribune,* November 9, 1939; "Newark Appeals in Airport Fight," *New York Times*, January 5, 1940, all in Box 85, New York, WPA Newspaper Files; "New York City Municipal Airport," *Aero Digest* 35 (November 1939): 33-36; Brehon B. Somervall, "New York Municipal Airport," *Civil Engineering* 10 (May 1940): 201-04; Brehon B. Somervall, "Servicing a Modern Airport," *Civil Engineering* 10 (May 1940): 295-98.

[109] "The Building of Washington National Airport," reprinted from *FAA World*, April 1979, Smithsonian National Air and Space Museum Technical Files, Air Transport Series, Airports, U.S., District of Columbia; "Commercial Airports near the Capital," *U.S. Air Services* 14 (May 1929): 48; "New Airport at National Capital," *Airway Age* 11 (August 1930): 1077-79; John Walter Wood, *Airports: Some Design Elements and Future Developments* (New York: Coward-McCann, 1940), 141.

[110] "Nation's Capital Working for Ideal Airport," *U.S. Air Services* 12 (January 1927): 28; Allen M. Smythe, "A Municipal Airport for Washington," *Aeronautic Review* 7 (January 1929); "Gravelly Pt. Airport Will Begin Soon," *Washington Post,* September 18, 1938; "Capital Airport Plan Approved by Roosevelt," *New York Herald Tribune,*

A Call for Federal Aid

Throughout the 1930s, cities aggressively sought federal aid for airport improvement. By the late 1930s, however, the link between airport improvement funds and work relief as well as the necessity of the local contributions required under WPA rules led cities to ask for more direct federal aid. In 1937, the American Municipal Association (AMA) issued a report emphasizing the role airports played in a national system of airways and airports. It argued that airport improvements not only benefited cities, but also states and the federal government. The report concluded with a resolution declaring that the federal government "should consider Federal responsibility for any projected federal airway program on a basis similar to the Federal responsibility in the national highway system and rivers and harbors."[111] Later that same year, the AMA sponsored a meeting between municipal representatives and the Bureau of Air Commerce. In response, the bureau created a committee "to propose plans for future development of the aviation industry, and to allocate responsibility for [those] municipal projects which also benefit state and Federal governments."[112]

The U.S. Conference of Mayors also examined the issue of municipal airports in 1937. It adopted a resolution in favor of federal aid to airports, declaring that while cities had borne most of the cost of creating the nation's airports, they could no longer shoulder this cost. As the federal government had aided other forms of transportation, so should it offer direct aid for airports. The resolution called on Congress to pass legislation "to provide for and authorize a permanent program of Federal financial cooperation in the construction, improvement, development and expansion of publicly owned airports."[113] Following the air crash that killed a U.S. Senator, Congress removed the ban on federal aid for airports under the Civil Aeronautics Act of 1938.

Civil Aeronautics Act of 1938

North of Kirksville, Missouri, a TWA DC-2 crashed in zero visibility on May 6, 1935, at 3:30 in the morning, killing five people including the U.S. Senator from New Mexico, Bronson M. Cutting. The Department of Commerce's investigation cited failures by the U.S. Weather Bureau and the airline. The bureau failed to detect and broadcast a weather change quickly. The airline—receiving the brunt of the blame—failed by allowing the plane to fly with an improperly working radio, waiting too late to reroute the plane to a field with better weather, and continuing the flight without adequate ground communication.[114]

The Senate conducted its own investigation and found the Department of Commerce and its Bureau of Air Commerce were also to blame and that problems existed with the bureau's procedures and navigation aids. The department and its bureau were reluctant to confess that its own rules and procedures may have contributed to the accident. Congress believed "that the bureau worked too closely with the commercial airlines and aircraft manufacturers to be

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September 28, 1938, both in Box 83, District of Columbia, WPA Newspaper Files; "Building of Washington National Airport," 2-3; "Washington National Airport," *Aero Digest* 38 (June 1941): 48-52.
[111] "Municipal Airports and Federal Responsibility," *American City* 52 (March 1937): 15.
[112] "A Year-End Message from the American Municipal Association," *American City* 53 (January 1938): 5.
[113] "Federal Aid for Airports," *American City* 53 (January 1938): 11.
[114] Solberg, *Conquest of the Skies*, 196.

objective. The bureau was supposed to promote commerce through aviation, but at the same time, it was to find the cause of accidents, even if that meant embarrassing itself or American companies."[115] A string of accidents over the course of the investigation further undermined public confidence in flying, with a total of thirty-seven people dying in air accidents that winter.[116]

Reflecting on its findings, Congress passed the Civil Aeronautics Act in 1938. The act vested responsibility for the nation's airways and airmail system in a newly created Civil Aeronautics Authority (CAA), removing it from the Post Office, the ICC, and the Bureau of Air Commerce. Out was the old contract airmail system where the needs of the Post Office came first. In was a system of negotiated, noncompetitive certificates, whereby any airline having a certificate could carry both airmail and passengers. Now, "the needs and preferences of the airlines and their passengers could be taken into consideration."[117] Writing in 1942, Henry Ladd Smith believed that civil aviation had been given a new constitution. The act, he said, was "the most important piece of air legislation ever passed by Congress."[118]

Following the Cutting crash, the Bureau of Air Commerce had "been under virtual siege." One Department of Commerce official, cited this incident as "the pivotal event in the background to the Civil Aeronautics Act.… And so it was that the Bureau of Air Commerce became a sacrificial pawn in a game played by the airlines to insure their own survival." Nick Komons points out, "the air carriers finally got their economic charter. They had broken loose from Post Office Department control, secured permanent rights to their routes, and rid themselves of the specter of competition. In the process, they had brought down the Bureau of Air Commerce—an act dictated more by political than substantive considerations."[119]

In the twelve years between the 1926 Air Commerce Act and the 1938 Civil Aeronautics Act, U.S. civil aviation had grown dramatically. Revenue miles flown increased from 4.3 million in 1926 to 69.7 million in 1938, an expansion made possible through federal air regulation and airway development. By the time of the Civil Aeronautics Act, "U.S. Airlines had assumed the aspects of common carriers, and they demanded to be treated according. And therein lies the chief significance of the Civil Aeronautics Act—it recognized that U.S. commercial aviation had come of age."[120]

This act, as noted, removed the ban on federal aid for airports. It also required the CAA to conduct a survey of the nation's public airports and make recommendations to Congress "as to whether the federal government shall participate in the construction, improvement, development, operation, or maintenance of a national airport system, and if so, to what extent, and in what

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[115] Roger Mola, "Accident Investigation," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Government_Role/accident_invest/POL17.htm (accessed March 5, 2004).
[116] Solberg, *Conquest of the Skies*, 198.
[117] Janet R. Daly Bednarek, *America's Airports: Airfield Development, 1918-1947* (College Station: Texas A&M University Press, 2001), 99. The act also lifted the ban on federal aid to airports and authorized the drafting of a national airport plan. Following reorganization in 1940, the Civil Aeronautics Authority became the Civil Aeronautics Administration.
[118] Smith, *Airways*, 303, 305. The CAA's headquarters were in the new Commerce Building with offices and bureaus scattered about the city. The agency was in various locations because it had no department affiliations and no building of its own.
[119] Komons, *Bonfire to Beacons*, 370, 378.
[120] Ibid., 379.

manner."[121] The CAA completed the survey in March 1939 and presented Congress a complex, three-stage development program, which, if fully implemented, would cost up to $435 million. Municipal officials objected, however, that the aid was still linked to work relief because most of the funding would come through the WPA. They argued that cities had already absorbed all the labor-intensive work needed. Instead, airports required funding for materials and equipment.[122] Timing, rather than municipal objections, proved the greatest obstacle. Though supporters also linked the program to national defense, Congress was reluctant to enact an extensive program designed for civilian airports and work relief in 1939. Instead, cities and airports would soon benefit from programs that more directly served national defense and preparedness.

[121] A. B. McMullen, "Airport: Development and Problems," *Journal of Air Law* 9 (October 1938): 651.
[122] Civil Aeronautics Authority, *Airport Survey: Letter from the Civil Aeronautics Authority Transmitting Recommendations as to the Desirability of Federal Participation in the Construction, Improvement, Development, Operation, and Maintenance of a National System of Airports* (Washington, DC: Government Printing Office, 1939): xiii, 129; "CAA Suggests Adoption of New Airport System," *Shreveport Times,* April 23, 1939, 21, Box 87, Misc., WPA Newspaper Files; Cy Caldwell, "Putting Our Airports on Relief," *Aero Digest* 35 (April 1939): 56; "The Problem of the Airport," *National Aeronautics* 17 (July 1939): 20.

BALLOONS AND SCIENTIFIC RESEARCH[123]

A great many balloon flights of the 20th century focused on science and, in particular, the sun and cosmic rays. Balloons provided a stable instrument platform free from the vibration and the electrical interference generated by aircraft engines and could also climb above most of the Earth's atmosphere and measure atmospheric and cosmic conditions without atmospheric interference. The 1930s saw an increase in the number of balloon flights into the stratosphere and Auguste Piccard, a Swiss physics professor and cosmic ray investigator, led the efforts. He had absolute faith that science could solve anything and considered the problem of oxygen deprivation, the central problem facing high-altitude balloonists, to be no obstacle. Using an apparatus developed by the Germans for use in submarines during World War I, Piccard designed a sealed pressurized gondola, 82 inches wide and weighing 300 pounds, to keep two people alive for up to 10 hours above 40,000 feet, the height at which air pressure becomes so reduced that a person's lungs cannot function and gases begin to bubble our of the blood. On May 27, 1931, Piccard and Paul Kipfer reached an altitude of 51,783 feet in a spherical, airtight, metal cabin suspended from a specially constructed, hydrogen-filled balloon.

Not to be outdone, the United States flew the *Century of Progress*, with a team headed by Auguste Piccard's twin brother Jean Piccard. Concerns regarding Jean Piccard's lack of a balloon license and worries that he would prove to be "a disruptive presence," caused the sponsors to sanction a solo ascent by Navy Lt. Cdr. Thomas G. W. "Tex" Settle, an accomplished balloon racer who had experienced success at the renowned Gordon Bennett Races. The first launch of the *Century of Progress* took place at Chicago's Grant Park Stadium on August 5, 1933, as a crowd of 20,000 spectators gathered to witness the balloon's ascent at 4:05 a.m. Unfortunately, a valve malfunction 15 minutes into the flight caused the balloon to drop onto the Burlington Railroad Tracks approximately two miles from the stadium.[124]

In a second launch on November 20, 1933, the balloon and pressurized gondola departed from Akron, Ohio, (where the balloon had been inflated in the Goodyear-Zeppelin hangar) and reached a record altitude of 61,237 feet, surpassing Piccard's previous record. The milestone flight, piloted by Tex Settle and Chester Fordney, marked the first time two Americans had traveled into the atmosphere in a pressurized cabin and the first time a balloon launched from American soil successfully reached the stratosphere. In addition, the *Century of Progress* enhanced scientific experimentation with two instruments to measure how gas conducted cosmic rays, a cosmic ray telescope, a polariscope to study the polarization of light at high altitudes, fruit flies to study genetic mutations for the U.S. Department of Agriculture, and an infrared camera to study the ozone layer.[125]

Jean Piccard's desire to fly into the stratosphere materialized the following year when he and his wife, Jeannette Piccard, who became the first woman to fly to the substratosphere, flew the refurbished *Century of Progress* safely to an altitude of 58,000 feet. In their October 22, 1934,

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[123] Portions of this section were excerpted or taken from Linda Voss, "Scientific Research Using Balloons in the First Part of the Twentieth Century," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Lighter_than_air/science-I/LTA14.htm (accessed February 17, 2004) and Linda Voss, "The Race to the Stratosphere," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/ Lighter_than_air/race_to_strato/LTA11.htm (accessed February 17, 2004).
[124] Ryan, *Pre-Astronauts*, 45, 47.
[125] Ibid., 46-47, 49.

experiments, a burst apparatus studied the simultaneous bursting of lead atoms bombarded by cosmic radiation, and physicist Robert Millikan of the California Institute of Technology supplied a cosmic radiation experiment, an ionization chamber shielded with 700 pounds of lead dust. The Piccards landed safely near Cadiz, Ohio.[126]

In 1934, the U.S. Army Air Corps, in cooperation with National Geographic Society, participated in high-altitude flights when Army Capt. Albert W. Stevens piloted the *Explorer I,* alongside co-pilot Maj. William Ellsworth Kepner, and operations officer Orvil A. Anderson. *Explorer I,* with its three-million-cubic-foot balloon, possessed five times the volume of the *Century of Progress,* making it the largest lighter-than-air craft at the time. Kepner and Anderson traveled throughout the western United States searching for a suitable launch site that would primarily shield the balloon from high wind gusts during its inflation. They located the ideal place in the Black Hills gold-mining country near Rapid City, South Dakota. First known as the Stratocamp and later as the Stratobowl, the site consists of a natural depression in the Black Hills, a flat plain of approximately 35 acres buffered by 300- to 500-feet sides of tree-lined banks and rugged limestone cliffs. On July 28, 1934, the *Explorer I* made its first flight amidst 30,000 spectators. Climbing to 60,613 feet and narrowly missing the world altitude record by 624 feet, *Explorer I* developed a rip in its balloon causing all three men to parachute to safety. At 5,000 feet the remaining hydrogen within *Explorer I* caused it to explode. The gondola came to rest in a Nebraska cornfield located four miles north of Loomis. According to balloon historian Jim Winker, the Stratobowl was the "Cape Canaveral of its day," garnering enough public attention to make it comparable to the manned space flights of the 1960s.[127]

The army quickly recuperated from the loss of *Explorer I* and planned a second ascent with the *Explorer II* fabricated by the Goodyear-Zeppelin Corporation. Its helium balloon, the first of its kind, minimized the risks of another gas-induced explosion. A crowd of 20,000 spectators watched *Explorer II,* and its 3.7 million-cubic-foot balloon, launch from the Stratobowl on November 10, 1935. Anderson and Stevens piloted the craft to 72,395 feet, setting a world altitude record that would stand for the next 21 years. Important milestones in reconnaissance took place during this ascent. Aerial photographs showed the division between the troposphere and the stratosphere and the curvature of the Earth, as Anderson and Stevens became the first humans to witness the curvature with the naked eye. Also, experiments involving cosmic ray research, the ozone layer, aeronomy (the science of the physics and chemistry of the upper atmosphere), meteorology, biology, and radio propagation in the high atmosphere were conducted during this eventful ascent. The craft landed in an open prairie field in the vicinity of White Lake, South Dakota. The flight marked the last high-altitude flight of the 1930s and the end of the great era of human stratosphere ballooning.[128]

Around the same time, Jean Piccard also teamed with physicist John Ackerman at the University of Minnesota to improve on the latex rubber balloons then used by experimenting with plastic film balloons. The only plastic then available for balloons was cellophane, a material susceptible

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[126] Ibid., 56. The other two members of the team were U.S. Noble laureates, Arthur H. Compton of the University of Chicago and Millikan, who had been responsible for coining the term "cosmic rays."
[127] Ryan, *Pre-Astronauts,* 51-55, 57; Black Hills National Forest, "Stratobowl Recognition Slated for October 6," news release, October 2, 2003; Crouch, *Eagle Aloft,* 619-622. The area surrounding the Stratobowl was known to locals as Moonlight Valley. Crouch, *Eagle Aloft,* 619.
[128] Ryan, *Pre-Astronauts,* 58-60; Smithsonian National Air and Space Museum, "*Explorer II,*" http://www.nasm.si.edu/research/aero/aircraft/explorer.htm (accessed October 12, 2004).

to cracking during cold weather inflations. They also tried using multiple latex balloons to lower the cost of balloons. On July 18, 1937, Piccard piloted the *Pleiades* on a successful low-altitude test flight carried aloft by 92 latex balloons. The enormous and heavy balloon envelopes had clearly reached the limits of rubberized fabric balloon technology. The absolute ceiling being between 40,000 and 50,000 feet where life could no longer be sustained had been breached by previous technology. Plastic balloon technology ushered in the next wave of exploration and high-altitude flights.

10. AERONAUTICAL TECHNOLOGY

Between the wars, aeronautical technology experienced a "design revolution." Much of this revolution was based on government initiative. In June 1920, the National Advisory Committee for Aeronautics (NACA) formally dedicated its first major research laboratory, the Langley Memorial Aeronautical Laboratory in Hampton, Virginia. The army's McCook Field moved to Wright Field in 1927. Activities at these facilities and others would gain momentum as technology moved from the strut-and-wire airplane to the mature propeller-driven airplane.[1]

Era of the Mature Propeller-Driven Airplane[2]

The test flight of the world's most successful series of commercial airliners began with a near disaster. On July 1, 1933, a sleek, aesthetically beautiful new airplane, the first commercial airplane ever designed by Douglas, took off from Clover Field, Santa Monica, California. The twin-engine DC-1, powered by two Wright Cyclone engines of 710 horsepower each, was designed to meet stringent specifications set down by Transcontinental and Western Air, Inc. (TWA). Jack Frye, vice president of TWA, who drafted the specifications, believed this airplane could revolutionize commercial air travel. Embodying the synergistic best of modern aeronautical engineering technology in 1933, the DC-1 held out the promise of being the most economic, most comfortable, highest speed, highest flying, and safest airplane in existence.

About 30 seconds after takeoff, the left engine quit; a moment later the right engine sputtered to a stop. As the airplane nosed over, however, the engines started again. The airplane began to climb only to have the engines stop again. After dipping the nose down, the engines re-started. For the next 10 minutes, the pilot put on a display of expert piloting, coaxing the DC-1 up higher along a sawtooth flight path, alternating between a climb, the engines cutting off, a nose over, the engines starting, and another climb until the engines quit again. At 1,500 feet, the pilot determined that the DC-1 was at a safe enough altitude to allow him to bank and return safely to the runway.

The airplane and its engines appeared to be mechanically sound. Over the next five days, in an attempt to find the flaw, the engines were taken apart and reassembled more than a dozen times. On the test block, the engines ran perfectly. On the fifth day, the mechanics, at the suggestion of the test pilot, examined the carburetors. To the amazement of the technicians, the carburetors, which metered fuel to the engine, had been installed backward. In this position, the carburetor floats cut off the fuel flow when the airplane was in a nose-up altitude. After rotating the carburetors 180 degrees, the DC-1 took off again in a second test flight. This time the engines performed perfectly.

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[1] For the evolution of NACA and its significance, see Roger Bilstein, *Testing Aircraft, Exploring Space: An Illustrated History of NACA and NASA* (Baltimore: Johns Hopkins University Press, 2001). For a definitive history of Langley Field, see James R. Hansen, *Engineer in Charge: A History of the Langley Aeronautical Laboratory, 1917-1958* (Washington, DC: Government Printing Office, 1987). An excellent source on McCook and Wright Fields is Lois E. Walker and Shelly E. Wickam, *From Huffman Prairie to the Moon: The History of Wright-Patterson Air Force Base* (Washington, DC: Air Force Logistics Command, U.S. Government Printing Office, 1986.)

[2] Much of this chapter is from John D. Anderson, Jr., "The Growth of Aeronautical Technology in America: Principal Players, Places, and Stories," (2005) submitted to the National Park Service for the draft *American Aviation Heritage* National Historic Landmarks Theme Study.

Essentially an experimental airplane, only one DC-1 was built. It was quickly followed by the look-alike but slightly larger DC-2. Douglas manufactured 156 of these planes in 20 different models that were used by airlines around the world. The DC-2, in turn, quickly evolved into the look-alike but still larger DC-3, the epitome of the mature propeller-driven airplane. The plane ultimately became one of the most successful airplanes in the history of flight and aeronautical engineering. When the DC-3 production line was finally shut down at the end of World War II, a total of 10,926 had been built.

In many ways, the DC-3 design exemplified the advances in aeronautical technology that occurred during the era of the mature, propeller-driven airplane. Unlike the preceding era in which U.S. engineering took a backseat to developments abroad, American aeronautical engineering now made the United States a world leader in aeronautical technology. The technological advances in airplane design were so significant that this period is also labeled the first "design revolution." Four particular technological advances and two areas of research support were reflected in the Douglas DC-3: aerodynamic streamlining, airfoil design, variable-pitch propellers, and the NACA cowling, developed with support generated from university aeronautical engineering programs and research done at Wright Field.

Aerodynamic Streamlining

The configuration of the DC-3 highlights drag reduction, which is the purpose of streamlining. Although the famous British aerodynamicist at Cambridge, Melvill Jones, as well as other aeronautical engineers in France and Germany had championed this streamlining, Douglas and Lockheed were the first to build a production-line streamlined aircraft. The DC-1, 2, and 3 series from Douglas and Lockheed's Vega, made famous by Amelia Earhart's cross-country flights using the aircraft, were the first of these planes.

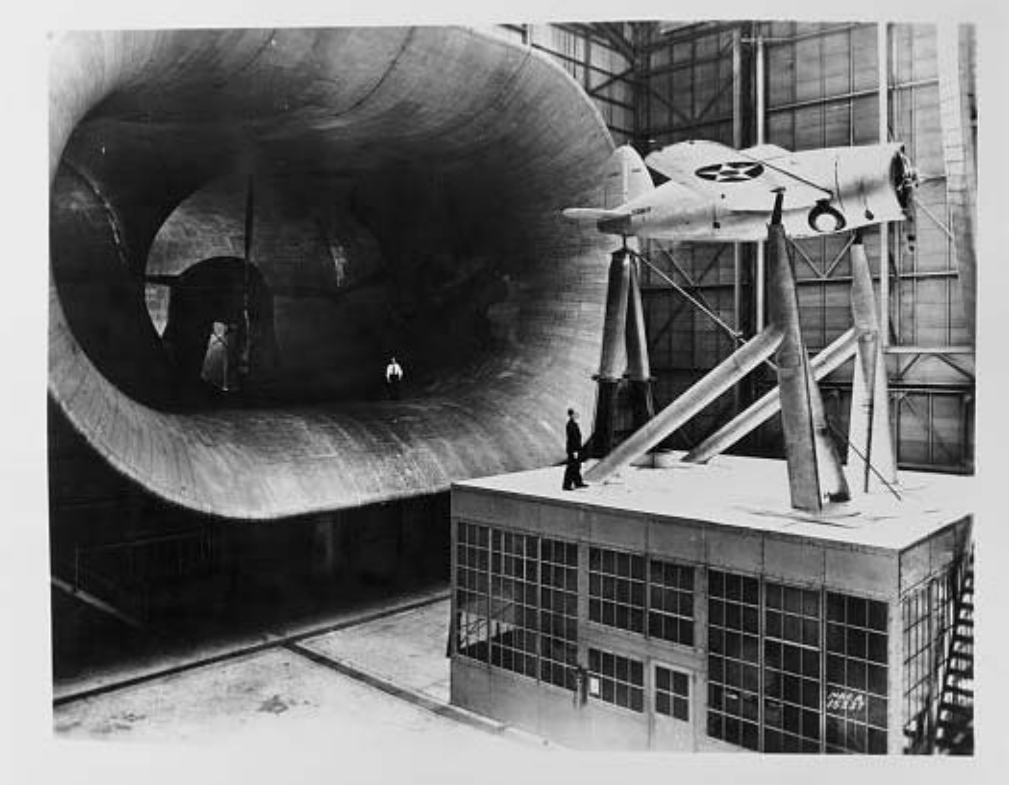
A new wind tunnel at the NACA Langley Memorial Aeronautical Laboratory assisted in the quest for drag reduction and streamlining. In 1931, a NACA wind tunnel with a 30-by-60-foot oval test section went into operation at Langley with a 129-mile-per-hour maximum wind speed in the test section. This was the first million-dollar tunnel in history.[3] Called the Full-Scale Tunnel, the tunnel had a test section in which whole airplanes could be mounted. Efforts to streamline airplanes and obtain drag reduction hit their zenith in this tunnel. In the late 1930s and 1940s, every effort was made to reduce or eliminate even the slightest sources of local flow separation on an airplane. In the laboratory, the best way to locate small regions of drag production was to dispense with small wind-tunnel models and instead put a real airplane in a wind tunnel. During the 1930s, the only wind-tunnel facility in which that kind of test could be conducted was the Full-Scale Tunnel at Langley. Here, NACA began a series of detailed, laborious wind-tunnel tests intended to reduce the drag coefficients for conventional airplanes as much as possible without interfering with practical operation. Within NACA those early wind-tunnel tests were collectively referred to as the "drag-cleanup" program. Begun in 1938, this program lasted essentially through the end of World War II.

The typical drag-cleanup process was one of parameter variation. The airplane was first put in its most faired and sealed condition (protuberances removed, gaps sealed, etc.), mounted in the wind tunnel, and the drag was measured. Then, one by one, each element was restored to its service condition, and the drag was measured each time. The increment in drag due to each

[3] Built during the Great Depression, NACA paid bargain-basement prices.

element was then determined. Although the drag increment for each element usually was small, the total accumulation from all of the drag-producing elements was usually large. The drag-cleanup series began in 1938 with the testing of a Brewster XF2A Buffalo single-seat U.S. Navy pursuit airplane. The navy had become concerned when the experimental prototype was unable to fly faster than about 250 miles per hour. The airplane was flown to Langley and mounted in the Full-Scale Tunnel. After detailed tests, a number of drag-producing protuberances were identified (landing gear, exhaust stacks, machine-gun installation, gun sight, etc.). These conclusions led to some modifications of the airplane, after which the maximum speed was found to be 281 miles per hour, a 31-mile-per-hour increase over the original prototype. The drag cleanup for the Brewster Buffalo was so successful that within 18 months 18 different military prototypes were tested in the Full-Scale Tunnel.

The drag-cleanup procedures represented an important step in the evolution of mature propeller-driven airplanes. Although the tests were mainly for military aircraft, they provided an educational experience and a massive aerodynamic database that would later be used to design aircraft of all types.



Typical drag-cleanup of the Brewster Buffalo U.S. Navy pursuit airplane in the full-scale wind tunnel, 1938. Source: Historic American Engineering Record, HAER VA-28-HAMP, 4-A-20.

Breakthroughs in Airfoil Design

An airfoil is any part of any aircraft designed to produce lift. The most obvious airfoil is the wing, but the propeller, tail, and fuselage may also be airfoils. Prior to the 1930s the design of airfoil shapes was ad hoc and customized; it was also poorly understood. In 1922, Virginius Clark, a noted aeronautical engineer who, as an army lieutenant colonel had been the commander of McCook Field from October 1917 to January 1918, gained fame as the designer of the famous

and ubiquitous Clark Y airfoil shape in 1922. He bemoaned the state of airfoil design in 1927: "it may be that we must, for a while forget about wind tunnels, for this particular purpose, and, as each new design problem arises, design an airfoil as we think it should be to best meet the requirements of the particular case—build out wings accordingly, and hope for the best in full flight results."[4]

Understanding and development of airfoil design changed dramatically in the early 1930s, primarily because of the work of Eastman Jacobs and the Langley Variable Density Wind Tunnel (VDT). This unique wind tunnel, which became operational at the laboratory in 1922, provided new means for obtaining realistic data on airplane aerodynamics. The flow circuit of the wind tunnel was placed inside a large pressure tank that was pressurized to 20 atmospheres (atm – a unit of pressure caused by the weight of atmosphere, which at sea level is 1 atm). The resulting higher density air of the wind tunnel flow helped to simulate the flow over a real wing 20 times the size of the model that was mounted in the wind tunnel. This allowed NACA to obtain aerodynamic data for airfoils (any part of an aircraft that is designed to produce lift) and wings that actually simulated full-scale flight conditions. On a more technical basis, this setup also allowed testing at full-scale Reynolds numbers, the ratio of inertial forces to viscous forces that is used to determine whether a flow will be smooth and constant or turbulent. With this facility, NACA leapfrogged over all the other existing wind tunnels in the world, and the experimental data obtained with the VDT made the United States the undisputed leader in applied aerodynamics for the next 15 years. In the words of aeronautical engineer Donald Baals and engineering and science writer William Corliss, "It was the VDT above all that established NACA as a technically competent research organization. It was a technological quantum jump that rejuvenated American aerodynamic research and, in time, led to some of the best aircraft in the world."[5]

Eastman Jacobs joined the Langley Memorial Aeronautical Laboratory in 1925, one year after graduating with honors from the University of California at Berkeley. He was soon recognized as an outstanding addition to the Langley staff, often taking innovative approaches to challenging problems. Assigned to the VDT, Jacobs played an important role in the early aerodynamic research of high Reynolds numbers. By the time of the NACA experimental airfoil program in the early 1930s, Jacobs had become head of the VDT section, a position he held for the next decade.

From April 1931 to February 1932, Jacobs and his colleagues carried out a series of airfoil measurements that provided a standard during the era of the mature propeller-driven airplane. Jacobs used a systematic approach to obtain what was to become the family of NACA "four-digit" airfoils (the four digits represent specific characteristics of the airfoil). The scheme was simple: construct a single curved line, called the mean camber line, and wrap a mathematically defined thickness distribution around the camber line. The lift and drag for the entire NACA family of airfoils were carefully measured in the VDT at Langley. The airfoil data from those studies were used by aircraft manufacturers in the United States, Europe, and Japan during the 1930s. The combination of Jacobs's engineering talent, the rational simplicity of the NACA design process, and the high Reynolds number conditions of the VDT had finally produced a useful database on the aerodynamic properties of airfoils. That contribution to applied

[4] John D. Anderson, Jr., *The Airplane: A History of its Technology* (Reston, VA: American Institute of Aeronautics and Astronautics, 2002), 230.
[5] Donald D. Baals and William R. Corliss, *Wind Tunnels of NASA*, NASA SP-440 (Washington, DC: NASA, 1981).

aerodynamics in the early 1930s was a major step toward the development of mature propeller-driven airplanes.

Jacobs also wrote the final chapter in airfoil research and design in the era of propeller-driven airplanes—the development of the laminar-flow airfoil. By the 1930s, it was well known that the skin-friction drag in a laminar flow over a surface was less (often considerably less) than that in a turbulent flow. Unfortunately, nature prefers turbulent flows, and therefore, it is extremely difficult (sometimes impossible) to maintain a laminar (smooth or constant) flow over a surface. Jacobs designed a completely new family of NACA airfoils with a shape that encouraged laminar flow over the surface. Tests carried out in a new airfoil wind tunnel at Langley showed that large regions of laminar flow did indeed exist over these airfoils and the skin-friction drag was correspondingly reduced. The design of the North American P-51 Mustang was the first production-line airplane to be based on these laboratory tests and to use a laminar-flow airfoil shape. In contrast to the ultrasmooth surface of the highly polished wind tunnel models, the realities of manufacturing introduced surface roughness and non-uniformities on the actual Mustang wings. Also, when used in the field, bug splatters and other foreign-object impacts added to the surface roughness. Such roughness encourages turbulent flow. Unfortunately, in the field, NACA laminar-flow airfoils experienced almost completely turbulent flow, like any other standard airfoil.

NACA laminar-flow airfoils were, however, a success in the end as they had excellent high-speed characteristics for flight close to the speed of sound. It was almost a fluke, one of those rare instances in the history of technology when a system becomes a success because it unexpectedly excels at something for which it was not originally designed. Because of their desirable high-speed characteristics, NACA laminar-flow airfoils were used on almost all high-speed airplanes in the 1940s and 1950s, and are still in use today.

In the end, the development of the laminar-flow airfoil series was the crowning achievement during a decade of important airfoil research by NACA when it was led by Eastman Jacobs. The 1930s brought an increased understanding of airfoil aerodynamics, and produced a massive collection of substantive wind-tunnel data on airfoils—significant factors in the development of mature propeller-driven airplanes.

Variable-Pitch Propellers

The Douglas DC-3 was one of the first production-line aircraft to be equipped with variable-pitch propellers. Even before World War I, aeronautical engineers knew that a propeller with a fixed pitch of the blades (the angle that the blades present to the incoming airflow) was most efficient at only one forward speed of the airplane. For all other speeds, slower or faster, the propeller operated less effectively.

Even before World War I, it was understood that designing a propeller with a pitch angle that could be changed in flight—a variable pitch propeller—could solve this problem. The Frenchman J. Croce-Spinelli made the first suggestion for a variable-pitch propeller in 1871. In 1876, the Frenchman Alphonse Penaud made the same suggestion. Because of the mechanical complexities of rotating the propeller, nothing came of these early suggestions. World War I provided a mild stimulation for work on variable-pitch propellers, with developments in Germany, England, Canada, and the United States, but, again, due to mechanical complexities, no practical solutions came from these efforts. Designing a mechanism that could take the wear

and tear of propeller operation presented problems. Another difficulty was the wooden propeller itself; attached to a variable-pitch mechanism, these propellers frequently disintegrated during testing.

The problem of variable pitch was not resolved until the metal propeller was developed, and both hydraulic and electric mechanisms were successfully designed for changing the pitch. These developments emerged simultaneously in the early 1930s, just in time for the higher performance airplanes that were the products of the design revolution. Frank W. Caldwell stands out as the principal designer of the first successful variable-pitch propeller.[6]

Caldwell attended the University of Virginia and the Massachusetts Institute of Technology (MIT), where he obtained a bachelor's degree in mechanical engineering in 1912. His undergraduate thesis entitled "Investigation of Air Propellers" contained pioneering ideas on propeller testing and launched him on a lifetime career dealing with propellers. After graduating Caldwell joined the Curtiss Aeroplane and Motor Company in Buffalo as foreman and process engineer in the propeller department. In 1917, he became the civilian chief engineer of the propeller department of the new aeronautical research and development facility at McCook Field, established by the Airplane Engineering Division of the U.S. Army Air Service. At McCook Field Caldwell began his work on both the metal and variable-pitch propellers.[7]

When Caldwell began his work at McCook Field, the aeronautical community was well aware of the need for both a variable-pitch propeller and better material than wood for its construction. In the NACA Annual Report for 1918, Chairman William F. Durand, himself an important contributor and expert on the fundamental aerodynamics of propellers while a professor at Stanford University, wrote that the invention of a variable-pitch propeller was "of the highest order of importance" as it was "one of the appliances for which the art of navigation is definitely in wanting."[8] Regarding the construction of a metal propeller, NACA identified it as one of the "very important problems now confronting the air services of the nation." In England, after the Royal Aircraft Factory at Farnborough built and flight tested a variable-pitch propeller, a report on the tests stated that "there can be little doubt about the aerodynamical advantages of the variable-pitch propeller." The mechanism used for varying the pitch, however, was still not satisfactory, and the same report threw cold water on the tests by stating that "the chief objections to the propeller are mechanical."[9]

Caldwell first developed a new multi-piece propeller, the detachable blades of which were fixed to a central hub; the mechanism for changing the pitch would be located in the hub. Then Caldwell searched for materials better than wood. After briefly experimenting with Bakelite micarta (so-called plastic propellers), he found that metal was a viable solution. As early as 1918, the propeller department began work on a drop-forged steel propeller and in 1920 contracted with the Standard Steel Propeller Company in Pittsburgh, Pennsylvania, to construct several different designs of steel propellers. Because of flutter problems and structural weakness where the steel blades were threaded to the propeller hub, this work was shelved in 1923.

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[6] See Jeremy R. Kinney, "Frank W. Caldwell and Variable-Pitch Propeller Development, 1918-1938," *Journal of Aircraft* 38 (September-October 2001): 967-76.

[7] McCook Field was a crossroads for a number of productive aeronautical engineers beginning in 1918 through the 1920s, such as Virginius Clark, who designed airfoil shapes and entire airplanes while at this facility.

[8] Jeremy R. Kinney, "Turning in the Wind: Frank W. Caldwell and the Variable-Pitch Propeller," *ITEA Journal* 30, (September 2009): 340.

[9] Anderson, *Airplane*, 256.

Caldwell then turned to duralumin (a special type of aluminum). Using duralumin blades, Standard Steel designed a new steel hub, split in two pieces, into which the individual duralumin propeller blades were clamped. This design allowed the pitch angle to be adjusted on the ground before a flight, picking a particular pitch angle that would be appropriate for the anticipated conditions of the flight. The U.S. Navy was interested in these propellers because one of its new Martin T3M torpedo bombers, powered by the 575-horsepower Wright T-3B Typhoon radial engine, lost a wooden propeller on takeoff. The procurement office quickly wrote a contract with Standard Steel ordering 100.

Problems with the development of new propellers at that time were illustrated by a story told by C. Fayette Taylor, director of the engine laboratory at McCook Field in the 1920s:

> In 1921 Caldwell tested a steel-bladed propeller on his electric whirling machine to twice its rated power. He then, very innocently, presented it to me for a "routine" test on a Hispano-Suiza 300 horsepower engine. After a few minutes at rated power, a blade broke off, came through the control board between the heads of two operators, climbed a wooden staircase, and went through the roof. The engine was reduced to junk.[10]

After leaving McCook Field, Caldwell became the chief engineer at Standard Steel in 1929. That same year, he patented a hydraulically actuated variable-pitch propeller that was lighter and easier to maintain than a mechanically actuated propeller. Standard Steel also merged with Hamilton Aero Manufacturing to create the Hamilton Standard Corporation, a component of the United Aircraft and Transport Corporation (United Technologies, today) that year. Hamilton Standard soon became the largest and most important manufacturer of propellers in the world, primarily because it furthered development of Caldwell's lighter and easier to maintain hydraulic variable-pitch propeller. Although Caldwell meant his design to allow continuous adjustment of the propeller pitch during flight, to save time the work at Hamilton Standard was concentrated on a two-position controllable pitch propeller: one setting for takeoff and another, activated by the pilot, for cruising flight. Only a halfway measure, this design proved a major success. It was ready for production in 1932, just in time to save the life of the new Boeing 247 transport. The performance of the first versions of the 247, with its fixed-pitch propellers, fell far below expectation, jeopardizing the whole project. Hamilton Standard sent Caldwell to Boeing to examine the problem. Through tests he demonstrated that the new variable-pitch propeller reduced the takeoff run of the 247 by 20 percent, increased the rate of climb by 22 percent, and increased the cruising speed by 5.5 percent. Boeing replaced the propellers on all its 247s with Hamilton Standard two-position controllable-pitch propellers, and the program was saved. Hamilton Standard, which was suffering financially because of the Depression, also benefited.

After Boeing adopted the variable-pitch propeller for the 247, other airplane companies and designers quickly saw its advantages. Douglas installed the two-position variable-pitch propellers on the DC-1, as well as the production versions of the DC-2. By the spring of 1934, Hamilton Standard had sold 1,000 of the new propellers. Moreover, by 1935 it had sold foreign rights for their manufacture to de Havilland in Britain, Hispano-Suiza in France, and Junkers in Germany.

Caldwell and Hamilton Standard shared the 1933 Collier Trophy for the two-position, hydraulically actuated, variable-pitch propeller. In presenting the award, President Franklin D.

[10] C. Fayette Taylor, *Aircraft Propulsion: A Review of the Evolution of Aircraft Piston Engines*, Smithsonian Annals of Flight, Vol. 1, No. 4 (Washington, DC: Smithsonian Institution Press, 1971), 77.

Roosevelt pointed out that the new propeller enabled "modern planes and engines to realize to the full the improvements in design." He went on to say, "The success of [Caldwell's] propeller has revealed a new horizon of aeronautics and taken the limits off speed. Henceforth, our pace through the air will be as fast as the daring and imagination of the engineers."[11]

Caldwell had always believed the ultimate propeller would be one where the pitch is continuously variable during flight, not set in just two positions. In fact, what made most sense was to have the pitch continuously and automatically changing so that the reciprocating engine would operate at constant speed (constant revolutions per minute) no matter what changes take place in the flight environment. The power output of a reciprocating engine is directly proportional to its revolutions per minute. By continuously changing the propeller pitch in the face of changing conditions, the load on the engine would be maintained to keep the revolutions per minute constant, close to the value corresponding to the engine's maximum power output. In this way, both the engine and the propeller are working synergistically to obtain maximum available power for flight. To help design a control that could handle frequent changes in engine speed, Caldwell employed the services of the Woodward Governor Company in Rockford, Illinois. In just two years, this team produced a working, constant-speed propeller. Hamilton Standard placed the constant-speed propeller in production in late 1935, just in time for it to be used on the new DC-3 by Douglas. Within four years, Hamilton Standard had sold more than 25,000 constant-speed propellers.

The NACA Engine Cowling

A significant technological accomplishment in the late 1920s was the NACA engine cowling (a removable metal covering), "one of the most successful aeronautical innovations of the twenties"[12] and one of the important aerodynamic developments in the era of the mature propeller-driven airplane. Its importance rested on the Wright J-5C "Whirlwind" power plant. Produced in 1925, this air-cooled engine became "the foundation for many radial engines that would power American aircraft through World War II and beyond."[13] Yet, the engine contained a design flaw. According to NACA tests, cylinders, exposed to the airstream to cool the engine, accounted for considerable drag.

The navy was partial to radial over liquid-cooled engines because of their solid performance on jarring carrier landings, "easier maintenance and power-to-weight ratio for operations from the limited confines of carrier decks."[14] In June 1926, the officials of the U.S. Navy Bureau of Aeronautics requested that NACA study how a cowling could be wrapped around the cylinders of radial engines so as to reduce drag without interfering with cooling capacity. The NACA cowling research was the first major test program to be carried out in the newly operational Propeller Research Tunnel (PRT) at NACA Langley. This large tunnel had a test section 20 feet in diameter and a maximum airspeed of 110 miles per hour. The test section could accommodate full-size airplane fuselages with installed engines and propellers. Fred Weick, a relatively young aeronautical engineer from the University of Illinois, had just become director of the PRT. Weick was given responsibility for NACA's cowling program because the PRT was the logical place to carry out the research. In less than a year, NACA had designed a cowling, the initial results for which showed a dramatic 60 percent reduction in drag. Within several years, virtually

[11] Kinney, "Turning in the Wind" *ITEA Journal* (September 2009): 342.
[12] Bilstein, *Enterprise of Flight*, 39.
[13] Crouch, *Wings*, 244
[14] Bilstein, *Enterprise of Flight*, 40.

all new American airplanes powered by radial engines used NACA cowlings. In 1929, NACA cowling won the Collier Trophy. This was the first of many Colliers to be won by NACA and its successor, the National Aeronautics and Space Administration (NASA).[15]

Aeronautical Engineering Education

A major expansion in aeronautical engineering education at the university level helped spur significant advances in aeronautical technology. Serious textbooks were now published on aeronautical engineering. Edward P. Warner, MIT professor, assistant secretary of the U.S. Navy for aeronautics, editor of the influential trade journal *Aviation,* and one of the best-known aeronautical engineers of that era, authored the classic *Airplane Design: Aerodynamics* (McGraw Hill). Published in 1927, Warner's book highlighted a maturing technology and provided an intellectual rigor not seen before in aeronautical engineering education.

Aeronautical engineering studies emerged in the early 20th century. Jerome C. Hunsaker, who had developed the first large wind tunnel and would be a key founder of the Naval Aircraft Factory, taught MIT's first aeronautics course in 1913. In that same year, Felix W. Pawlowski, a professor in mechanical engineering who trained in Poland and France, started another pioneering program in aeronautical studies at the University of Michigan.[16]

These and other university programs greatly benefited from philanthropist Daniel Guggenheim. The idea to fund a school of aeronautics first began after Guggenheim's son, Harry, a former naval aviator in World War I, became interested in a proposal by Alexander Klemin to organize an aeronautical engineering department at New York University. A graduate of Hunsaker's program at MIT, Klemin had become director of MIT's aeronautics program after Hunsaker left in 1916. He then served as the officer-in-charge of the Research Department at the army's McCook Field during World War I. Worried that the public might not appreciate the value of the project, Harry Guggenheim persuaded his father to fund and endow a Guggenheim School of Aeronautics at the university's College of Engineering.[17]

Daniel Guggenheim now considered whether he should create a multi-million dollar fund to support the growth of civil aviation. Both Daniel and Harry Guggenheim discussed the idea with Orville Wright, Secretary of Commerce Hoover, President Coolidge, and others. By January 1926, Daniel Guggenheim had decided to forge ahead. "The Daniel Guggenheim Fund for the Promotion of Aeronautics would support aeronautical education; fund research in 'aviation science'; promote the development of commercial aircraft and equipment; and 'further the application of aircraft in business, industry and other economic and social activities of the nation.' Running it would be a blue-ribbon panel of leading figures from aviation, business, finance, and science, including the inventory of the airplane and a Nobel laureate in physics."[18]

Between 1926 and 1930, the fund endowed six schools of aeronautical engineering at American

[15] NACA became NASA in 1958. The NACA never applied for a patent for the cowling. H. L. Townend of the British National Physical Laboratory had earlier developed a narrow ring, called the Townend ring, that was considered "an important step forward" in reducing drag. Bilstein, *Enterprise of Flight*, 38.
[16] Donald M. Pattillo, *Pushing the Envelope: The American Aircraft Industry* (Ann Arbor: University of Michigan Press, 2003), 47; Roger E. Bilstein, *The Enterprise of Flight: The American Aviation and Aerospace Industry* (Washington, DC: Smithsonian Institution Press, 2001), 38.
[17] Tom D. Crouch, *Wings: A History of Aviation from Kites to the Space Age* (New York: W. W. Norton, 2003), 236-37; Bilstein, *Enterprise of Flight*, 38.
[18] Crouch, *Wings*, 237.

universities: California Institute of Technology, Stanford University, University of Washington, University of Michigan, Massachusetts Institute of Technology, and the Georgia School of Technology (later to become the Georgia Institute of Technology). Guggenheim funds supported the programs existing at both Michigan and MIT, and created new departments of aeronautical engineering at the four remaining schools.

The importance of these early university programs to the advancement of aeronautical technology in America cannot be overemphasized. Among the leading airplane designers and aeronautical scientists who graduated from these programs was the 1932 Michigan graduate Clarence "Kelly" Johnson who went on to become arguably the most famous airplane designer of the past 70 years.[19] "Nationwide, the growing pool of trained aeronautical engineers," states historian Roger Bilstein, "played an important role in assisting in the design of planes that elevated aviation and air travel to a reliable, economical, and mature technology."[20]

Wright Field: The Army Marches On

The rapid expansion of aeronautical technology in the late 1920s and early 1930s, and the resulting design revolution, caused the army's aeronautical engineering activities to outgrow its limited space at McCook Field. Personnel and equipment from McCook Field were moved lock, stock, and barrel to Wright Field, and McCook Field was quickly closed down. On October 12, 1927, the new Wright Field held its dedication ceremonies, open to the public, with spectacular exhibition flying and racing. Located approximately 10 miles east of the city of Dayton, it included the land of the older Wilbur Wright Field that dated back to World War I. Land was abundant at Wright Field, with 750 acres located on the protected side of Huffman Dam (the present-day Area B of the massive Wright-Patterson Air Force Base), and 3,800 acres in the flood-control basin of the Mad River. This expansive area of land (especially the 750 acres now constituting Area B) was soon to become the site of major advances in U.S. aeronautical technology.[21]

After delays in constructing the building for it, the large five-foot wind tunnel at McCook Field began operation at Wright Field in 1929. For decades afterward, wooden airplane models with wingspans up to 20 inches were tested in this wind tunnel at airspeeds as high as 270 miles per hour. The McCook Field 14-inch wind tunnel also continued to be used at Wright Field for the testing of airfoil and propeller sections up to speeds of 465 miles per hour; it was among the fastest wind tunnels in the United States in the early 1930s.

In addition to aerodynamic testing, the Structures Development and Test Laboratory put Wright Field engineers at the forefront of aircraft stress analysis and experimentation. They perfected static and dynamic testing to state-of-the-art levels for the late 1920s and the 1930s. This laboratory was one of the best equipped in existence.[22] At the beginning of the era of the mature propeller-driven airplane, when strut-and-wire cloth covered biplane configurations were

[19] More than any other engineer, Johnson made Lockheed's design reputation. Pattillo, *Pushing the Envelope*, 84. Johnson designed the famous P-38 from World War II, the P-80 Shooting Star which was America's first mainline jet fighter, the U-2 high-altitude spy plane, and the Mach 3+ SR-71 Blackbird, among many others.
[20] Bilstein, *Enterprise of Flight*, 39. "By 1929, a survey by one aviation magazine reported a total of 1,400 aeronautical engineering students enrolled in 14 colleges and universities across the United States."[20] Bilstein, 39.
[21] For a description of the move to Wright Field and the ceremonies, see Walker and Wickam, *From Huffman Prairie to the Moon*, 118-22.
[22] Ibid., 131.

becoming history, the aeronautical engineers at the Structures Laboratory accelerated the development of the modern all-metal monocoque airplane.

The Propeller Research and Test Laboratory tested every new type of propeller used by the army. In the 1930s, this laboratory had the largest propeller test facilities in the world. The electric power demands for these propeller test devices were so large that a special dispatcher's office at Wright Field had to coordinate testing schedules with the Dayton Power and Light Company.

Engine testing and refinement, always an important activity at McCook Field, became even more important at Wright Field. The Power Plant Branch ran three major laboratories, the Dynamometer Laboratory for measuring detailed performance of engines; the Torque Stand, an imposing structure of seven 40-foot stacks open to the sky for measuring the horsepower of high-power engines; and the Fuel Test Laboratory for testing fuels and lubricants. The Power Plant Branch tested every new engine design bought by the army. Moreover, its research on liquid-cooled engines resulted in these engines making a comeback after their eclipse by the rapid development of radial engines. A number of U.S. Army fighter airplanes in World War II used liquid-cooled engines, allowing for highly streamlined fuselages, all due to the work at Wright Field.

NACA was not the only source of important contributions that influenced the manufacturing lines of American aircraft builders. The Daniel Guggenheim Fund for the Promotion of Aeronautics sponsored several ventures, including a milestone project in 1929 that led to appropriate instrumentation for "blind flying." The electronic equipment for this project came from the Aircraft Radio Corporation (ARC), a leading pioneer in the field located in Boonton, New Jersey. Lt. Jimmy Doolittle used special ARC instruments to take off from ARC's airfield, circle the field, and land successfully while sitting in a hooded cockpit (although a backup pilot occupied the other cockpit). This advance led to vastly improved operational activities for aircraft flying at night and in bad weather.

The military services oversaw a number of aviation installations, laboratories, and testing facilities that explored specific issues relating to combat flying and military operations. In particular, over the course of McCook's Field's 10-year existence, the engineers and scientists advanced propeller technology; they developed new propeller materials that led to widespread use of the metal propeller in the late 1920s; and pioneered the development of the variable-pitch propeller that led to its first production in the early 1930s. New airplanes designed at McCook Field ranged from the Messenger, the smallest Air Service plane in service, to the Barling Bomber, the largest airplane of its time. Engineers at McCook Field contributed to aerial photography, communications, armament, parachutes, high-altitude flight, engine development, instruments, and a host of other aeronautical engineering developments. The technological advancement of military aviation in America during the era of the strut-and-wire biplane owes much to the work done at McCook Field.

During the 1920s and 1930s, the study of high-altitude flying and research, as well as wind tunnels, special installations for the testing of propellers, structural testing, analysis of instruments, and related activities were also explored at laboratories. One of the earliest U.S. Navy facilities grew from a naval air station at Anacostia Field near Washington, D.C. There, the navy carried out test flights of several planes under evaluation for naval service. In 1934, it became a center for investigating instrument landing techniques aboard aircraft carriers. At Dahlgren, Virginia, home of the Naval Proving Ground (later the Naval Surface Warfare Center),

a small aviation unit established in 1918 devised procedures and developed equipment for spotting naval gunfire and for conducting dive-bombing attacks.

Conclusion

In the 1930s, the two most powerful government laboratories responsible for the advancement of aeronautical engineering technology in the United States were the NACA Langley Memorial Aeronautical Laboratory and Wright Field. Basic and applied research in aeronautics was the major role of Langley, whereas advanced aeronautical development was the forte of Wright Field. Langley carried out some flight test activities of a more basic nature on military and civilian airplanes; while Wright Field was the centerpiece for test-flying and improving the performance of virtually all military aircraft designs for the army, along with some civilian airplanes.

The list of airplanes flight-tested at Wright Field is a veritable encyclopedia of U.S. Army aircraft. Wright Field was *the* place for the army where aeronautical engineering technology developed and flourished. Its impact on the advancement of aeronautical technology in America is immeasurable by any quantitative means because the research and development carried out by Wright Field simply became an essential part of America's aeronautical engineering culture, absorbed and assimilated by thousands of aeronautical engineers in industry, government, and academia.

The same can be said for the work of NACA at Langley. During the 1930s, the aeronautical work at Langley intentionally focused on research, basic and applied, and at the time, the activities of Wright Field emerged as a potential competitor to Langley. To avoid future problems and duplication, the aeronautical technical work at Wright Field was oriented toward advanced development. An extreme example of this policy occurred in the late 1930s. When engineers at Wright Field wanted to build a new high-speed wind tunnel to probe some of the mysteries of high-speed flight near the speed of sound, the plan was not approved because Langley was considered to be the government laboratory where such new wind tunnels and research should be carried out. Unfortunately, this division of research responsibility tended to inhibit the building of new state-of-the-art research-oriented wind tunnels at Wright Field until after World War II when Hap Arnold and his scientific advisor Theodore von Kármán pioneered a new direction into advanced research and technology.

11. MILITARY AVIATION BETWEEN THE WARS

> *[F]or the first time in history, Air Power that you could put your hand on.*
>
> *--Gen. Henry H. "Hap" Arnold's comment regarding delivery of the first B-17s to Langley Field, Virginia, in 1937.*[1]

The golden age of aviation in America produced tremendous progress in both civil and military aviation. Pushing the limits of aircraft performance in airshows, races, and long distance flights had two benefits. First, these shows provided testing for technological innovations in aircraft and engines. Second, they garnered public support for Congressional funding. "Military funding and operational requirements were critical forces driving the development of a strong and technologically progressive American aviation industry."[2]

Throughout the early 1920s, fighter planes continued to be biplane designs constructed of wood, wire, and fabric. They still had open cockpits and reached top speeds of only 150 to 170 miles per hour, with operational altitudes of about 15,000 to 20,000 feet. The design and operational performance of military aircraft changed dramatically between the wars. By 1941, when the United States entered World War II, fighter planes had evolved into all-metal monoplanes with enclosed cockpits; these new planes could reach speeds approaching 400 miles per hour and operated at altitudes of 35,000 feet and more. Planes were not the only equipment to undergo substantial changes during this period: the dirigible, the autogiro, or helicopter, and the aircraft carrier also evolved to become more effective. The evolution of aircraft sparked a need for greater training of pilots and crew members and for substantial improvements in air fields and manufacturing.

Between the wars airmen set out to formulate policy and doctrine regarding airpower, create an organization, and establish a training system that laid the foundations of American air power in World War II. Throughout this period, two issues were hotly debated: the question of whether an air force, independent of the army and navy, was truly necessary and its corollary, whether airpower would continue to be supplemental to land and sea battles or whether it would be the dominant face of war. The growing technological sophistication of bombers which could reach and pinpoint industrial and transportation targets shaped these debates over the potential of military aviation and a coherent theory of airpower.

ARMY AVIATION

The Army Air Service, 1918-1926

William "Billy" Mitchell & the Drive for Independence

America's top combat commander in Europe during World War I, William "Billy" Mitchell, briefly remained in Europe following the war as head of the Air Service for the U.S. occupying

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[1] Jody Cook, "Langley Field, Virginia: 'The Forgotten Birthplace of American Air Power'?" 1998 National Aerospace Conference Proceedings (Wright State University, April 30, 1999), 137.
[2] Charles J. Gross, *American Military Aviation: The Indispensable Arm* (College Station: Texas A&M University Press, 2002), 48.

force in Germany. In March 1919, at the behest of Maj. Gen. Charles C. Menoher, director of the Air Service and a nonaviator, Mitchell returned to the United States to head its Training and Operations Group. Mitchell was dedicated to creating an independent air force. His conviction stemmed from his time with General Hugh Trenchard, commander of the Royal Air Force which had been established as an independent air force on April 1, 1918.[3]

Mitchell's Training and Operations Group became a breeding ground of pro-independent air force activity, although not specifically for strategic bombing. Mitchell realized that arguing for an offensive bomber group was neither politically nor doctrinally acceptable for the Air Service in 1919. The Air Service had a defensive function and strategic bombing would not be well received within President Wilson's administration. Wilson's secretary of war, Newton Baker, was adamantly opposed to any doctrine that intimated attacks on cities and civilians.[4] Baker also saw the success of American aviators during World War I as evidence that an independent air force was unnecessary for victory. Baker's view prevailed and when President Wilson signed the National Defense Act of 1920, the new legislation made the Air Service a permanent combat arm of the army.[5] Staff reorganization under this act made Menoher Chief of the Air Service and Mitchell the Assistant Chief.

While Mitchell's crusade for air power garnered enthusiasm among some army airmen, he met stiff opposition from the public, military, and Congress. The isolationism that followed the armistice shaped this opposition as did military strategists' belief that aviation was nothing more than a supplement to ground forces. Failing to build his case for military aviation with the government, Mitchell mounted a "bold campaign of publicity and aerial accomplishments."[6] To educate and publicly promote the air service, Mitchell sponsored long-distance, high-speed, and high-altitude flights.[7] Military aviators competed successfully in wildly popular air races and also became the first to circle the globe in a 175-day trip in 1924.[8]

In 1921, Mitchell conducted his most prominent campaign for an independent service when he decided to wrest control of the coastal defense mission from the navy air services. Gaining control, Mitchell reasoned, would be a monumental step towards independence. Convinced that aviation was the wave of the future, Mitchell set out to demonstrate the potential military power of aircraft. In February of 1921, Mitchell testified before a House subcommittee on aviation, arguing that 1,000 bomber aircraft could be built and operated for the cost of a single dreadnaught, the navy's enormous steam-propelled battleships then being funded by Congress.[9] Military aircraft, Mitchell believed, could defend the country against hostile fleets. Mitchell

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[3] Roger G. Miller, *Billy Mitchell: "Stormy Petrel of the Air"* (Washington, DC: Office of Air Force History, 2004), 24. Under Trenchard, the RAF "had developed a strategic component, but in practice it had remained committed to direct support of the British army."
[4] Miller, *Billy Mitchell*, 25.
[5] John F. Shiner, "From Air Service to Air Corps: The Era of Billy Mitchell," in *Winged Shield, Winged Sword: A History of the United States Air Force*, vol. 1, ed. Bernard C. Nalty (Washington, DC: Air Force History and Museums Program, 1997), 75-76, 92. Unlike other combat arms, the Air Service would manage its own research and development, and control its own personnel recruitment and training. However, the Chief of the Air Service did not have command of operational air units. Gross, *American Military Aviation*, 54.
[6] Shiner, "Air Service to Air Corps," 86.
[7] Tom D. Crouch, *Wings: A History of Aviation from Kites to the Space Age* (New York: W. W. Norton, 2003), 229.
[8] Shiner, "Air Service to Air Corps," 90.
[9] Pamela Feltus, "Billy Mitchell Sinks the Ships," U.S. Centennial of Flight Commission, http://centennialofflight.gov/essay/Air_Power/Mitchell_tests/AP14.htm (accessed March 11, 2004).

challenged the navy to accept Air Service participation in tests it was conducting on the effects of bombs on warships. A confident navy brass accepted.[10]

Mitchell then assembled planes and pilots from Air Service bases across the nation for extensive training in the temporary 1st Provisional Air Brigade at Langley Field in Hampton, Virginia. That July, airplanes and pilots demonstrated the military potential of the airplane by destroying three decommissioned U.S. battleships (a destroyer, an armored light cruiser, and a dreadnought) as well as the *Ostfriesland*, a comparatively modern German battleship, in a military exercise.[11] For Mitchell, the sinkings proved that the battleship was inferior to the airplane and that aircraft could defend U.S. coasts from a naval invasion at a lower cost than the army's coast artillery and the navy's warships.[12] Although the navy recognized the airplane as a powerful offensive weapon, they also pointed to several factors that had eased Mitchell's job. The "ships had been at anchor and unable to maneuver. There were no crews or equipment aboard to provide damage control and keep them afloat. And the total absence of defensive antiaircraft fire gave the attackers a free hand. Finally the weather was good and a line of destroyers had guided the bombers to their targets. A hostile fleet was unlikely to provide these advantages."[13]

Basking in the great publicity the bombings had generated, Mitchell went one step further on his return trip to Langley Field when he staged simulated attacks on New York City, Baltimore, Philadelphia, Wilmington, and the United States Naval Academy at Annapolis. His subsequent report on the bombing trials called for an independent air force. "In essence, Mitchell concluded, Americans could no longer look to the oceans for protection. Airpower had changed the equation, making the nation vulnerable to attack." Leaked to the *New York Times*, the report caused a public sensation.[14] Maj. Gen. Menoher, unable to control Mitchell, was furious. He issued an ultimatum to Secretary of War John W. Weeks, insisting that either he or Mitchell would have to leave.[15] The secretary removed Menoher and replaced him with Maj. Gen. Mason M. Patrick, Gen. John J. Pershing's chief of aviation in France and a professionally trained engineer. Unlike Mitchell who favored public confrontations and sensational headlines, Patrick coordinated behind-the-scenes maneuvers to successfully promote the development of military aviation.[16]

Assessing the overall effect of Mitchell's bombers, Charles J. Gross maintained that the campaign made little impact beyond generating considerable public controversy. "The bombing tests failed to convince either senior government officials or the public," Gross asserts, "that America needed to base its national security on a separate air force built around long-range

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[10] Gross, *American Military Aviation*, 54.
[11] Cook, "Langley Field, Virginia"; Crouch, *Wings*, 230; Shiner, "Air Service to Air Corps," 94-95. In contempt of Mitchell, the Secretary of the Navy offered to stand bareheaded on the bridge of any ship the army attempted to bomb. Fortunately that secretary left office prior to the army's July 1921 bombing. Shiner, "Air Service to Air Corps," 94.
[12] Shiner, "Air Service to Air Corps," 95.
[13] Miller, *Billy Mitchell*, 33.
[14] Ibid., 34.
[15] Gross, *American Military Aviation*, 56.
[16] "To better understand the needs of his young aviators and gain their respect, Patrick earned his pilot's wings when he was nearly sixty years old." "From 1921-27, he guided the army's air arm to a realistically achievable degree of autonomy." Gross, *American Military Aviation*, 57.

bombers."[17] Under Patrick, Mitchell continued his drive for an independent air force and solidified his views on bombing. He believed that long-range bombers could achieve victory by attacking deep inside enemy territory, destroying transportation networks and war-making machinery. In 1923, "Mitchell produced and distributed his own bombing manual…'Notes on the Multi-Motored Bombardment Group,' which was far ahead of his time, although not the clarion call for strategic bombardment as it would later develop….Much of what Mitchell advocated was unavailable in 1923, but as a blueprint for air warfare twenty years in the future, his bombing manual was a *tour de force*."[18]

Unfortunately, Mitchell's occasionally abrasive manner and his unbridled zeal for air power antagonized many policy makers and political leaders, eventually leading to the end of his military career. When Mitchell publicly criticized national military policy in 1925, he was demoted and reassigned to San Antonio, Texas. After a naval flying boat disappeared on a flight from California to Hawaii in the summer of 1925 and the naval airship *Shenandoah* crashed in September, Mitchell publicly accused the War and Navy Departments "of incompetency, criminal negligence, and almost treasonable administration of the National Defense." His words led to charges of insubordination and President Calvin Coolidge ordered Mitchell court-martialed. Following his conviction on December 17, 1925, and a five-year suspension of duty, Mitchell resigned from the army on February 1, 1926, but he continued to advocate for airpower through speaking tours, articles, and books until his death in 1936.[19] Although Mitchell alienated those with whom he disagreed, he "inspired devotion among his followers, engendering a belief in himself and in the future of air power."[20]

The Army Air Corps, 1926-1935

The Air Corps Act of 1926

Months before Mitchell's trial, President Coolidge initiated an investigation into aviation policy in an attempt to lessen the trial's public and political impact. Coolidge asked his close friend, Dwight Morrow, an investment banker, to head the President's Aircraft Board, informally known as the Morrow Board, to explore the general subject of aviation. Before the conclusion of Mitchell's court martial in 1925, the group issued its findings. The board recommended that the government create an Air Corps within the army, provide a new Assistant Secretary of War for military aviation, and create a five-year program to improve the Air Corps and increase its officers, enlisted men, and serviceable aircraft. These recommendations became law on July 2 when Congress approved the Air Corps Act of 1926. Although a watershed for the army's aviation branch, insufficient funding in subsequent years kept the Air Corps from fully realizing its goals. The Air Corps Act did, however, bring "a temporary equilibrium to the struggle over organization and control" between the air leaders and the War Department General Staff, but air leaders themselves remained divided between equalization and independence.[21]

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[17] Gross, *American Military Aviation*, 55.
[18] Miller, *Billy Mitchell*, 37.
[19] Lt. Col. Johnny R. Jones, "William 'Billy' Mitchell's Air Power" (Maxwell Air Force Base, AL: Airpower Research Institute, September 1977), xiii, http://www.cadre.maxwell.af.mil/ar/mitchell/front.pdf (accessed June 23, 2005); Shiner, "Air Service to Air Corps," 98-99.
[20] Quotes from Shiner, "Air Service to Air Corps," 100; John F. Shiner, "The Coming of the GHQ Air Force, 1925-1935," in *Winged Shield, Winged Sword*, vol. 1, 122.
[21] Thomas H. Greer, *The Development of Air Doctrine in the Army Air Arm, 1917-1941* (Washington, DC: Office of

When the Army Air Corps was created, two plans for the use of airpower existed. One plan supported by the General Staff and the War Department represented the traditional view toward airpower. Air Service Training Regulations (TR) 440-15, *Fundamental Principles for the Employment of the Air Service*, dated January 26, 1926, recognized "the principle of concentration of combat aircraft and the possibilities of some kind of strategic operations." The second plan, supported by a majority of the air officers, was published in the April 1926 textbook *Air Service Tactical School*. It contained "the most advanced theories regarding the nature of war and the function of military aviation." This view became the focus of air theory at the school and its "text well represents the prevailing attitude of the Air Corps Tactical School, which from 1926 until 1941 opposed (almost to the point of heresy) the doctrinal assumptions of the War Department."[22]

Air Theory

The Air Corps Tactical School originally opened on October 30, 1920, as the Air Service Field Officer's School, and it was later renamed the Air Service Tactical School in 1922. The first school of its kind, it sought "to equip student officers with the air tactics and techniques necessary for direction of air units in cooperation with other branches of the armed forces." Because air operations were still viewed as auxiliary to ground battles, students were originally trained in accordance with the "prevailing conservative, ground-oriented concept of war." However, with the emergence of bomber models in 1925, instructors and students began to advocate a broader role for aircraft than simply providing support for ground forces.[23] Before 1926 minimal progress had been made in bomber design, but in the early 1930s, the Martin B-10, a long range bomber, shifted the debate about air power. With its twin engines, retractable landing gear, a ceiling of 28,000 feet, and speeds of 200 miles per hour, this all-metal aircraft met the needs of strategic bombardment.[24] Development of the B-10 marked a turning point in bombardment weapons and America would retain a dominant position in military aviation technology for years.[25]

After 1926, the school became the center for a new air theory, one which introduced the idea of strategically bombing the enemy's industrial and commercial centers. Every year a class of about 50 officers converged upon the school and investigated all aspects of military aviation through field problems, formal lectures, and spirited debates. Students and faculty emphasized the role the long-range bomber would play in future wars as well as their belief "that the bombers of the next war would be able to fight their way to the industrial and administrative centers of the enemy and destroy the very means of making war, avoiding a long and bloody land

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Air Force History, 1985), 28-29, http://www.airforcehistory.hq.af.mil/Publications/fulltext/development_air_doctrine_army_air_arm.pdf (accessed March 28, 2006).

[22] Ibid., 40.

[23] Ibid., 29; Cook, "Langley Field, Virginia," 134.

[24] Roger E. Bilstein, *Flight in America: From the Wrights to the Astronauts* (Baltimore: John Hopkins University Press, 2001), 126-27.

[25] Greer, *Development of Air Doctrine*, 46. The B-10 was preceded by the twin-engine B-9 bomber. Produced in 1931, the B-9 was the first monoplane bomber to reach active duty with the Air Corps, and its all-metal structure represented an important step into the future. Roger E. Bilstein, "Flying High: The Aviation Manufacturing Industry in the United States," (2005) prepared for the draft *American Aviation Heritage* National Historic Landmarks Theme Study, 30.

campaign aimed at defeating the hostile army."[26] In 1931, the school moved from Langley Field to Maxwell Field in Alabama, where it became "a who's who of U.S. Army Air Force commanders."[27]

Air Corps Training Facilities

Between the Armistice in November 1918 and July 1919, the War Department bought and maintained fifteen flying fields, as well as five balloon stations, to meet plans for advanced training in bombardment, pursuit, gunnery, and observation. These sites joined existing fields at Rockwell in California, Langley in Virginia, Post (at Fort Sill) in Oklahoma, and Kelly Field No. 1 in Texas. Between 1919 and 1922, the Air Service created professional training programs. By March 1919, primary training was conducted at March Field in Riverside, California, and Carlstrom Field in Florida. In July 1920, the Observation School at Post Field opened.

Unfortunately, a shortage of manpower in the early 1920s necessitated closure of some training fields. March Field closed first and by June 1921, only Post Field offered advanced training in observation while Kelly Field maintained bombardment training. A year later, pilot training moved from Carlstrom to the Primary Flying School at Brooks Field in San Antonio, Texas, while Kelly Field maintained the Advanced Flying School. The Balloon and Airship School was located at Scott Field in southwestern Illinois.[28]

The five-year program established in the Air Corps Act of 1926 enabled the Air Corps to increase the number and quality of its installations. In August 1926, the Air Corps Training Center was established at San Antonio for pilots of heavier-than-air craft. The center also supervised primary training at Brooks Field as well as the reopened primary flying school at March Field, the advanced flying training program at Kelly Field, and the School of Aviation Medicine at Brooks Field. The Air Corps Training Center Headquarters was then located at Duncan Field near Brooks and Kelly. The Balloon and Airship School at Scott Field, the sole place for lighter-than-air craft, ceased operations in 1928.[29]

The five-year program also called for a new primary flying school. Located northeast of San Antonio, Randolph Field [NHL, 2001] became operational in October 1931 as the headquarters for the Air Corps Training Center and the place for all primary flight training. Randolph was the first field built specifically as a permanent air station. Brig. Gen. Frank P. Lahm, one of the very first army pilots, was responsible for directing the selection of a new airfield northeast

Historic post card of training plane over Randolph Field. Courtesy of Jody Cook.

[26] Shiner, "Coming of the GHQ Air Force," 111-12.
[27] Crouch, *Wings*, 385.
[28] Rebecca Hancock Cameron, *Training to Fly: Military Flight Training, 1904-1945* (Washington, DC: Air Force History and Museums Program, 1999), 222, 224, 228, 229; Shiner, "Air Service to Air Corps," 81; Shaw, *Locating Air Force Base Sites*, 14.
[29] Shiner, "Coming of the GHQ Air Force," 81, 108-11; Frederick J. Shaw, ed., *Locating Air Force Base Sites History's Legacy* (Washington, DC: Air Force History and Museums Program, 2004), 17-19; Cameron, *Training to Fly*, 246, 253.

of San Antonio, Texas; he was also instrumental in designing the new training center to be designated Randolph Field. Working with Lt. Harold L. Clark, an engineer from the Office of the Chief of the Air Corps, Lahm conceived an entirely novel idea, a circular field rather than a grid pattern. All phases of flying training—primary, basic, and advanced—would proceed in a clockwise direction around the field with administrative and support facilities located at the center of the complex. Randolph Field became touted as the West Point of the Air.[30]

General Headquarters (GHQ) Air Force, 1935-1939

The creation of a centrally controlled strike force led to a compromise in the debate over an independent air service. Establishment of the General Headquarters Air Force at Langley Field on March 1, 1935, placed all army combat aviation, for the first time, under a single command. Although part of the army and intended to support land forces, the GHQ Air Force was free to conduct independent air missions. This revolutionary change in the organization of the Army Air Corps formalized the shift of military aviation from air *service* (focused primarily on defense) to an air *force* (with independent strategic implications) and gave the Air Corps the opportunity to demonstrate the offensive potential of airpower. It was also "the single most important step thus far toward independence." Under the GHQ Air Force the Chief of the Air Corps had authority over individual training at the flying fields, while the Training Section reviewed the instructional programs at the Air Corps Tactical School, and the Primary and Advanced Flying Schools.[31]

A Changing War Doctrine

Airpower advocates believed that the most effective way of ending future conflicts quickly with a minimal loss of life was a bombing campaign directed at the enemy's cities rather than at troops. "What evolved into the theory of strategic bombing began with a simple assumption," says historian Tami Davis Biddle, whereby "aircraft, specifically long-range or 'strategic' bombers, can avoid an enemy's army and navy and proceed directly to its 'vital centers,' where they can cause enough destruction and disruption to induce surrender on terms favorable to the attacker." Strategists theorized that a campaign of this type would be both a psychological and a physical battle, with the effect of undermining civilian morale. Precision bombing targeting key industries was also thought to be more humane with the loss of fewer civilian lives.[32]

This doctrine became reality with the development of the Boeing B-17 "Flying Fortress," widely viewed by the military as the first real strategic bomber. Introduced in the late 1930s, the B-17 was equipped with new bombsights developed by the Norden and Sperry companies and designed to bomb specific bottleneck targets. Its performance, along with the earlier appearance

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[30] Jerold E. Brown, *Where Eagles Land: Planning and Development of U.S. Army Airfields, 1910-1941* (New York: Greenwood Press, 1990), 80, 134.

[31] Quote, John L. Frisbee, *Makers of the United States Air Force* (Washington, DC: Air Force History and Museums Program, 1996), 5; Shiner, "Coming of the GHQ Air Force," 130; Cook, "Langley Field, Virginia," 138; Greer, *Development of Air Doctrine*, 70. GHQ had two other regionally based wings at March Field and Barksdale Field in Louisiana.

[32] Pamela Feltus, "The Prophets: Advocates of Strategic Bombing," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Air_Power/Prophets/AP11.htm (accessed March 11, 2004); Tami Davis Biddle, "Strategic Air Warfare: An Analysis," in *Reconsidering a Century of Flight*, ed. Roger D. Launius and Janet R. Daly Bednarek (Chapel Hill: University of North Carolina Press, 2003), 190.

of the Martin B-9 and B-10, "and the promise of even greater things to come, sharply stimulated the development of air doctrine." With the development of the high-speed bomber, the overall development of air theory at the Tactical School emphasized bombardment over pursuit.[33]

In late 1938, as America prepared for war, the Air Corps sharpened its vision of an air doctrine still further. By August 1941, officers, who had been chosen by Gen. Arnold and who had all been instructors at the Air Corps Tactical School, submitted a plan that the War Department approved on September 11, 1941. In just nine days, using the ideas they formulated at the school, these officers prepared the "AWPD-1 [Air War Plans Division] that ultimately became 'the blueprint for the air plan to defeat Hitler'."[34]

[33] Greer, *Development of Air Doctrine*, 47, 55.
[34] Phillip S. Meilinger, *Significant Milestones in Air Force History* (Washington, DC: Air Force History and Museums Program, n.d.), http://www.au.af.mil/au/awc/awcgate/af/sigmilestones.pdf (accessed January 24, 2011).

NAVAL AVIATION

Like the army, the navy had conflicting views and controversies on how to develop aviation after World War I. Factional infighting centered on whether the navy should create an independent offensive operation or stay with the patrol and reconnaissance mission it conducted during the war. Those within the major faction who advocated patrol work were divided over whether seaplanes, floatplanes, or lighter-than-air craft would best meet the mission. Long-range seaplanes operating from seagoing tenders or land bases possessed strategic mobility. Floatplanes (a type of seaplane with pontoons) could take off from battleships and cruisers and conduct "gunfire spotting, scouting, and air defense of the fleet." And lastly, lighter-than-air craft could conduct wide-ranging patrols over vast oceanic expanses. The major faction advocating aircraft carriers did so for their potential use in tactical reconnaissance, spotting gunfire, maintaining air superiority over fleet engagements, and employing aircraft against submarines and surface ships.[35]

As World War I came to an end, the navy asked Congress for funds to explore each of these avenues for aviation. In October 1918, naval leaders requested funds to convert both four rigid airships and two hangars, convert a collier into an experimental aircraft carrier and two merchant vessels into seaplane tenders, and purchase of two British airships. Only the USS *Wright* seaplane tender was commissioned. "[T]hose preliminary steps foundered because of tight budgets, doctrinal confusion, and the absence of a strong organizational champion for aviation at the highest levels of the battleship-oriented navy."[36]

Finally in 1919, a naval bill allocated funds specifically for the construction of two sheds for dirigible storage, the purchase of an airship from abroad, and the domestic construction of a dirigible. To this end, a naval air station at Lakehurst, New Jersey, was established. Considerable funds and planning also went into improving the design and construction of flying boats. Given the navy's commitment to long-range patrols for detecting both submarines and hostile surface forces, naval planners were especially interested in crossing the Atlantic. In 1919, a Curtiss tri-motored bi-plane (the NC-4) flew across the Atlantic, making intermediate stops in Nova Scotia, Newfoundland, and the Azores before reaching Portugal. As the first transatlantic flight, this trip received a great deal of positive press for the navy.[37]

The navy benefited, as had the army, from bureaucratic evolution. Proposals for a separate aviation bureau in the Navy Department, which had been left unresolved for years, solidified following Gen. Mitchell's bombing trials in 1921. Alarmed admirals banded together and supported legislation to create the Bureau of Aeronautics. The bureau's first chief was Rear Admiral William A. Moffett, "a Naval Academy graduate and respected military insider who was popular on Capitol Hill." An early skeptic of flying who had stated "that any man who flew was either crazy or a damned fool,"[38] Moffett came to vigorously support aviation, often at the expense of funding battleships; he also became skilled at countering Mitchell's attacks.[39]

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[35] Gross, *American Military Aviation*, 53.
[36] Ibid., 53-54.
[37] Bilstein, "Flying High," 21-22.
[38] M. Hill Goodspeed, "A Golden Journey," U.S. Naval Aviation, http://www.hlla.com/reference/naval-aviation.html (accessed September 8, 2005).
[39] Gross, *American Military Aviation*, 55.

Moffett served as head of the bureau for twelve years and is widely regarded as the "architect of naval air power."[40] Among his accomplishments, Moffett integrated the tactical use of airplanes and airships with fleet operations, hastened the transformation of the navy from a "battleship navy" to a "carrier navy," and rationalized procurement to bring stability to the burgeoning American aircraft industry.[41]

Aircraft Carriers

Moffett was a patient advocate of the navy's ambitious program to build its carrier fleet. Despite a rising sentiment in favor of disarmament and forceful arguments against surface ships by General Mitchell, the navy began to shift its focus from battleships to the development of carriers to replace thin-skinned battle cruisers. As a politically savvy officer, Moffett believed U.S. airpower was "dangerously underdeveloped" but, unlike Mitchell who insisted upon an independent air force, Moffett believed the navy needed its own air arm operating from carriers.[42]

The first attempt at creating a carrier emerged in the early 1920s when the navy converted the USS *Langley*, a coal transport, to a flat-topped carrier. But this craft was slow and could generally carry no more than seventeen fragile biplanes.[43] Naval treaties signed early in the 1920s allowed the navy to revise its plans for a pair of fast cruisers and use them instead as the basis for a pair of truly modern aircraft carriers. The *Lexington* and *Saratoga* featured wide decks and could carry 81 aircraft each. These ships were commissioned in 1927, and along with the *Langley*, shaped naval strategy and tactics.[44] Historian Charles Gross describes their role:

> Existing doctrine called for such ships to remain in protected positions behind the battle line in fleet engagements. Initially, their primary roles were to provide air cover for the fleet, locate the enemy, and then spot the gunfire of American warships. The latter enormously increased the potential power of warships by enabling them to accurately engage targets far beyond the horizon at the full range of their main batteries.[45]

When Franklin Roosevelt assumed the presidency in 1933, the former assistant secretary of the navy proved to be an advocate of sea power as well as airpower. The USS *Yorktown* [NHL, 1986] and USS *Enterprise* were part of the National Industrial Recovery Act of 1933, which was designed to create employment. Begun in 1934 and commissioned in 1937 and 1938 respectively, these two ships formed the basis of what would become the Essex class, capable of carrying 100 aircraft each. At the time of Pearl Harbor, only eight aircraft carriers were in commission.[46] "Although battleships were still seen as the most critical element of sea power,

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[40] Pattillo, *Pushing the Envelope*, 37.
[41] David Nevin, *Architects of Air Power* (Alexandria, VA: Time-Life Books, 1981), 68; "Rear Admiral William A. Moffett 1869-1933," http://moffetthistoric.arc.nasa.gov/history/WmMoffett.html (accessed September 8, 2005).
[42] Nevin, *Architects of Air Power*, 68.
[43] Gross, *American Military Aviation*, 67.
[44] Ibid., 69; Thomas C. Hone, Norman Friedman, and Mark D. Mandeles, *American & British Aircraft Carrier Development: 1919-1941* (Annapolis, MD: Naval Institute Press, 1999), 30-31.
[45] Gross, *American Military Aviation*, 69.
[46] Andrew Faltum, *The Essex Aircraft Carriers* (Charleston, SC: Nautical & Aviation Publishing Company of America, 1996), 6; Gordon Swanborough and Peter M. Bowers, *United States Navy Aircraft since 1911* (Annapolis, MD: Naval Institute Press, 1990), 3.

the concept of the independent fast-carrier task force had emerged and was becoming firmly embedded in naval doctrine."[47]

Aircraft

Moffett also proved successful in procuring new aircraft. In 1925, the navy had just over 200 working aircraft, many of which were World War I vintage and/or shore-based. In the next year, Moffett used those statistics combined with the rancor over the plight of military aviation produced by Mitchell's court-martial to persuade Congress to authorize a naval aviation modernization program. Initially estimated at a cost of $85 million over five years, this program ultimately received enough funds to reach "its goal of a thousand modern aircraft by the end of 1931."[48]

Japan's renunciation of naval arms limitation treaties and its invasions of China prompted the United States to begin a naval rearmament program in January 1938. Congress approved spending $1.1 billion to double the navy's aircraft inventory to 3,000 (in addition to expanding the fleet beyond treaty limits and building two new carriers). The new generation of all-metal monoplane naval aircraft featuring enclosed cockpits, retractable landing gear, and powerful engines, matched the latest army aircraft. The army, on the other hand, received a paltry $17 million, and its Air Corps received nothing at all. Angry army airmen pointed out that their new B-17 bombers were more important than battleships and aircraft carriers as the nation's first line of defense. "They argued that the naval rearmament program was designed to promote an interventionist foreign policy but failed to sidetrack it on Capitol Hill."[49]

Dirigibles

Moffett was also the "navy's most important supporter of the rigid airship."[50] Using the expertise of the Naval Aircraft Factory in nearby Philadelphia, and Lakehurst's new hangar facilities [Hangar No. 1, NHL, 1968], the navy assembled its first dirigible, the *Shenandoah*, in 1923. In the following year, the *Los Angeles*, an airship completed in Germany as part of that country's war reparations payments, was also assigned to the American navy. Throughout the 1920s, both dirigibles attracted considerable news coverage, although budgetary issues led to the decommissioning of the *Los Angeles* in the early 1930s. At the same time, two advanced dirigibles had already made their debuts in navy service—the *Akron* and the *Macon*.

The Goodyear Airdock in 1985. Source: Historic American Engineering Record, HAER Ohio, 77-Akro, 6-2, 1985.

[47] Gross, *American Military Aviation*, 71.
[48] Ibid., 59.
[49] Ibid., 81.
[50] Crouch, *Wings*, 293.

The Goodyear Tire and Rubber Company became the principal contractor for both rigid and non-rigid airships; the mammoth Goodyear Airdock at Akron's municipal airport served as the fabrication facility for both the *Akron* and *Macon*. As a rubber and tire corporation, the Goodyear Company had a unique expertise in industrial chemistry, specifically the use of industrial gasses like helium, as well as the production of rubberized and chemically treated fabric. Goodyear now dominated its competitors in the use of rubberized material and related products, the processes needed to fabricate the very large internal cells to hold helium gas, the fabrication of non-rigid blimp types, and the extensive external envelope covering required for the huge rigid dirigibles.[51]

Goodyear proved invaluable in supplying the military with blimps and kite balloons, training pilots, advancing balloon technology, and standardizing operating procedures and techniques. Twenty-six airships were constructed at Wingfoot Lake for use by the army, while kite balloons were built for use by both the military and Goodyear. Consequently, Goodyear heightened its involvement in the blimp industry by enlarging the aeronautical department and by forming the Goodyear-Zeppelin Corporation for the construction of rigid airships for the navy.[52]

The missions of these airships, together with the evolving role of the small, non-rigid blimp for shorter reconnaissance missions and for convoy duties, underscored the importance of maintaining helium production at the government's facility in Texas, the Amarillo Helium Plant. The need for helium gas had led the government to the Amarillo region where the development of oil fields had also led to the discovery of copious supplies of hydrogen gas in the same geographic area. A federally sponsored helium extraction plant assured the navy of an adequate helium supply and also established an American monopoly on the worldwide production of this commodity.

The 1930s brought an end to the dirigible era. The *Shenandoah* had already experienced a dramatic crash in 1925; both the *Akron* and *Macon* proved to have drawbacks for extended operations in foul weather, and both seemed vulnerable to sharp wind shifts. The *Akron* went down at sea during a storm off New Jersey on April 4, 1933. The crash killed 73 of the 76 on board including Adm. Moffett. "His tragic death, in the crash of the dirigible *Akron*… robbed the navy—and the aviation community—of an articulate and effective spokesman."[53] In a less horrific outcome, the *Macon* went down off the coast of San Francisco in 1935, killing 2 of the 83 crewmen. "The age of the American rigid airship," states Tom Crouch, "was at an end."[54]

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[51] Bilstein, "Flying High," 23.

[52] P. Rendall Brown, "History & Blimp Basics, 'A Brief History of the Wingfoot Lake Airship Base'," http://www.goodyearblimp.com/wingfoot.html (accessed February 20, 2004)." In June 1919, Goodyear began construction of its own airships while fulfilling government contracts with the navy. The company built and operated the first commercially licensed blimp in the United States, the helium-inflated *Pilgrim*. Between 1917 and 1941, a little more than 100 airships were assembled and tested at Wingfoot Lake.

[53] Bilstein, *Flight in America*, 46.

[54] Crouch, *Wings*, 294.

MANUFACTURING

After the armistice in November 1918, orders for at least 61,000 aircraft were canceled, and by the summer of 1919, about 90 percent of peak production capacity had disappeared. At the conclusion of the "war to end all wars," Congress gave little attention to new military aircraft needs.[55] In the 1920s, the young aviation industry, almost entirely dependent on military contracts, deteriorated rapidly.

Recognizing that the aviation industry was critical to fostering technological progress, General Patrick and Admiral Moffett took major steps to reduce two sources of direct competition, the Air Service's Engineering Division at Wright Field and the Naval Aircraft Factory (NAF) in Philadelphia. Both facilities had been established during World War I to design and build prototypes of new aircraft and engines. For his part, Patrick ordered the Engineering Division to develop military requirements for prototype aircraft and engines which manufacturers would then submit to the Engineering Division for testing. Moffett required the same of the NAF, however, "the NAF continued developing aircraft prototypes to serve as yardsticks for gauging industry costs."[56]

Although the military aircraft industry continued to struggle throughout the Depression, "many developments during 1927-1935," writes Donald Pattillo, "…make a persuasive case that those years were in fact the golden age for the industry."[57] Milestone achievements by NACA, Wright Field, the private industry, and manufacturers combined to produce the streamlined all metal monoplane, a new breed of modern pre-jet aircraft. New features such as air-cooled radial engines, low-drag engine cowlings, controllable-pitch and constant-speed propellers, retractable landing gear, and enclosed cabins rendered the old-fashioned military biplanes of World War I obsolete.[58]

Design and Production for the Military Market

During the 1920s, the Douglas Aircraft Company, as one of the manufacturers which won a series of modest orders for military designs, correspondingly expanded its design and production facilities. The company was led by Donald Douglas, a graduate of the Massachusetts Institute of Technology (MIT) where he had assisted Professor Jerome Clarke Hunsaker in building a pioneering wind tunnel. By the time Douglas left MIT in 1918, he had a background of formal and theoretical training in aeronautical matters that few of his contemporaries possessed. Following his wartime positions with Glenn Martin's company, Douglas decided to launch his own design office in Santa Monica, California. There, the mild climate reduced operational costs for large assembly buildings and the weather promised a large percentage of days for flying. Douglas also found financial support from newspaper and petroleum financiers there.

Douglas' early combat planes for carrier operations included biplane types such as the DT (D for Douglas, T for torpedo bomber) purchased by the navy in 1921. The DT was a two-place, fabric-covered biplane—a large, single-engine design (powered by surplus Liberty engines) with

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[55] Gross, *American Military Aviation*, 63; Pattillo, *Pushing the Envelope*, 39.
[56] Gross, *American Military Aviation*, 63.
[57] Pattillo, *Pushing the Envelope*, 64.
[58] Gross, *American Military Aviation*, 64-65.

fixed landing gear, but distinguished by its specially engineered wings, which could be folded back along the fuselage to take up less space on carrier decks or in hangar space below decks. Three years later, the DT became the basis for a modified type known as the Douglas World Cruiser. Ordered by the U.S. War Department under a contract for five aircraft, a pair of these planes completed a flight around the world in a little over six months. Worldwide headlines made the Douglas name famous, and the company forged ahead. By the late 1930s, an all-metal monoplane dive-bomber, the SBD Dauntless (Scout Bomber Douglas), operated by a pilot and an observer/gunner in a rear seat, had replaced the DT designs. This new aircraft was powered by a Wright radial engine of 1,200 horsepower, had retractable landing gear, and the wings automatically folded inboard for compact stowage aboard carriers. The first deliveries began in 1940 and production ended in July 1944. Along with fighters from Grumman, the Douglas Dauntless played a key role in the Battle of the Coral Sea (May 7-8, 1942). As navy fighters engaged enemy aircraft, the Dauntless squadrons carried out bomb and torpedo attacks against Japanese carriers and naval vessels, becoming the first naval combat engagement fought entirely by carrier-based planes.[59]

Aircraft developed by the Grumman Aircraft Engineering Corporation also experienced a similar evolution in design and construction. Leroy Grumman was a navy ensign who relied on Grover Loening as a liaison for naval contracts. After leaving the service in 1920, Grumman became a test pilot and engineer for the Loening organization, and when Loening decided sell out in 1930, Grumman founded the Grumman Aircraft Engineering Corporation. The new firm set up shop on Long Island, eventually established headquarters at Bethpage, New York, and managed to survive the early years of the Great Depression. Grumman developed a reliable landing gear that retracted into the sides of a plane's fuselage; its dependability and the rugged design of Grumman's amphibian planes attracted increasing interest from the navy. In 1931, this interest led to the Grumman FF-1 (F was the navy's designation for the manufacturer—the G had already been assigned—F for fighter, and 1 for the first of this type), a plane that featured a Wright Cyclone radial engine, a NACA cowling, and stressed-skin metal construction. The latter technique, also known as monocoque construction, used the metal skin itself as a major element in the plane's load-bearing structure. The FF-1 also introduced retractable landing gear into the ranks of carrier-borne combat planes. A biplane, it became the first of series of such types delivered by Grumman through the 1930s; these naval aircraft from Grumman and others also equipped U.S. Marine combat squadrons.

Following the armistice of 1918, designs from the Boeing Company in the Pacific Northwest won modest but ongoing contracts from the army and navy. By 1927, the Boeing Company listed 800 employees and enjoyed a reputation as one of the nation's leading aviation manufacturers. For years, the company operated from a cavernous, two-story wooden building affectionately known as the "Red Barn," because of its bright red paint and white-trimmed windows. As business grew, adjacent facilities were used for aircraft production. By this time, the Red Barn had become the design center for a growing staff of Boeing engineers. During the mid-1930s, the Air Corps had begun to think about truly long-range aircraft for strategic attacks against enemy production and transportation facilities located far behind the front lines. Subsequently, the Red Barn's engineers began sketching the outlines of a dramatic step ahead in

[59] Roger E. Bilstein, *The Enterprise of Flight: The American Aviation and Aerospace Industry* (Washington, DC: Smithsonian Institution Press), 23-25; Ray Wagner, *American Combat Planes*, 3rd ed. (Garden City, NY: Doubleday & Company, 1982), passim.

the design of long-range bombers—Model 299, which evolved into a four-engine aircraft eventually known as the B-17 "Flying Fortress."

In California, Douglas also built a series of biplane aircraft with a configuration similar to those produced by Boeing, Grumman, and other suppliers of the era. During the mid-1930s, Douglas won a navy contract for a new, modern torpedo bomber built for operations from aircraft carriers. By this time, Douglas focused its production of naval aircraft at a facility located in El Segundo, California. For the new navy bomber, specifications called for a single-engine monoplane, enclosed cockpit, and retractable landing gear. The first production models of the TBD-1 Devastator, capable of speeds over 200 miles per hour, flew in 1937. With advanced military aircraft like the Devastator, and with the success of larger twin-engine civil aircraft like the DC-3 transport, Douglas successfully combined this experience into an advanced, twin-engine light/attack bomber as a private venture, designated the DB-7, which first flew in 1938. Although the DB-7 was intended to meet an anticipated Air Corps requirement for such an aircraft, early production orders came from British and French purchasing missions, who dubbed it the Boston.

A trim, modern-looking design in every respect, the DB-7 used a tricycle landing gear and early export versions mounted a pair of Wright Cyclone engines of 1,600 horsepower each. The Air Corps soon adapted it with a designation of A-20 Havoc. The plane had a wingspan of 61 feet, room in its bomb bay to carry 2,000 pounds of ordnance (with underwing racks, some versions could carry up to 4,000 pounds), and a top speed of 340 miles per hour, a good performance for planes entering service in the late 1930s and early 1940s. It also came well armed for its missions, with a pair of machine guns in a dorsal position (another gun was usually fitted in a ventral position), and two or four fixed machine guns to fire forward. Not always recognized for its contributions as a successful combat plane of World War II, the A-20 not only served in its original role of light attack bomber, but went through considerable modifications for other types of missions. With the Plexiglas (used for visual observation by the bombardier/navigator) removed from its nose and replaced by a battery of machine guns and cannon, it became an effective plane for strafing ground targets. Later in the war, additional U.S. Air Force models of the A-20 carried early versions of airborne radar and operated as night fighters. Operated by American air forces, as well as those of Britain, Commonwealth nations, the Soviets, and Free French squadrons, deliveries of the A-20 came to over 7,300 aircraft. Its service history represented an impressive record of production along with military adaptability for designs from the United States.[60]

As the second manufacturer chosen by the War Department to build an intercontinental bomber, Douglas responded with the XB-19. Its wingspan of 212 feet (at the time, the longest to be engineered and built) was nearly half again as long as the wing built for Boeing's XB-15. The latter tipped the scales at a mere 37,700 pounds empty; the XB-19 weighted in at a hefty 84,431 pounds empty and 140,000 at gross weight. The XB-19 was the largest plane built to have a tricycle landing gear, and the single tires of its huge main gear were as tall as the average Douglas engineer. As it turned out, they did not distribute the weight of the plane very evenly as it taxied around airfields, and the plane often left a trail of cracked taxiways in its wake. This

[60] Wagner, *American Combat Planes*, 172-78; Philip Moyes, *Royal Air Force Bombers of World War II* (New York: Doubleday, 1969), 44-52; David Donald, ed., *The Complete Encyclopedia of World Aircraft* (New York: Barnes & Noble Books, 1997), 348-49.

glitch led to the practice of building other large aircraft to have dual tires for the main gear as well as the nose gear. The design and construction of jigs for the plane's assembly became a major engineering effort of its own. The newly named Army Air Force took delivery of the plane in 1941, and it proved to be a useful test-bed for subsequent combat equipment and engines, although the Douglas aircraft, like its Boeing counterpart, spent the war years as an occasional transport. Nonetheless, both of these unique, experimental bombers contributed valuable experience in the design, engineering, and operation of very large aircraft, a bank of knowledge useful in both wartime and peacetime.[61]

Rotary Wing Aircraft[62]

Although vertical flight remained very much in its infancy, the military saw its potential early on. Shortly after World War I, Henry Berliner, the son of Emile Berliner who had designed the first rotary engine, the 36 horsepower Adams-Farwell engine, began experimenting with vertical flight. He built a counter-rotating coaxial rotor machine that made brief uncontrolled hops to a height of about four feet while steadied from the ground. Between 1922 and 1924, Berliner used College Park Airfield [College Park Airport, NR, 1977] in College Park, Maryland, to conduct experiments with his helicopter. In 1922, he improved the design by mounting two coaxial counter-rotating rotors on the wingtips of a Nieuport 23 biplane fuselage; the navy supplied him with more powerful engines. The incorporation of sets of movable vanes—flat surfaces mounted under the rotors—provided some control to the machine. In June 1922, it hovered around 12 feet off the ground and was successfully demonstrated to the U.S. Army. On February 24, 1924, using an English Bentley engine, the Berliner Helicopter No. 5 successfully maneuvered in all directions, obtained a speed of about 40 miles per hour, and ascended to an altitude of 15 feet. The Berliner aircraft is considered the first rudimentary piloted helicopter developed in the United States. The navy and the media were present to witness the first controlled helicopter flight.[63]

The army was not to be outdone. During this period, a Russian immigrant to the United States, the mathematician and scientist George de Bothezat, designed and built a four-rotor machine under the sponsorship of the U.S. Army. The machine was known as the "Flying Octopus." Maj. T. H. Bane, chief of the Airplane Engineering Division of the U.S. Army Air Service at McCook Field in Dayton, Ohio, was a staunch advocate of rotary flight and its military advantages, which included battlefield liaison duties, evacuations and other similar tasks.[64] When Bane pointed out "that the United States was the only great power in the world not engaged in constructive experimentation with rotary-wing aircraft and the helicopter principle of flight," the army contracted with de Bothezat to design and supervise the construction of the first

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[61] Bill, Yenne, "Experimental Bomber, Long Range," *International Air Power Review* 5 (Summer 2002): 164-72; Jones, *U.S. Bombers*, 55-58; Frank Cunningham, *Sky Master: The Story of Donald Douglas and the Douglas Aircraft Factory* (Philadelphia: Dorrance, 1943), 278-91.

[62] Portions of "First Vertical Flight Machine" excerpted from Judy Rumerman, "Helicopter Development in the Early Twentieth Century," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Rotary/early_20th_century/HE2.htm (accessed December 2, 2004).

[63] Edmund Preston, Barry A. Lanman, and John R. Breihan, *Maryland Aloft: A Celebration of Aviators, Airfields and Aerospace* (Crownsville: Maryland Historical Trust Press, 2003), 34; College Park Aviation Museum, "Berliners," http://www.pgparks.com/places/historic/cpam/3berlineres.html (accessed February 11, 2005).

[64] Bilstein, *Flight in America*, 117; Hollingsworth Franklin Gregory, *The Helicopter: A Pictorial History* (Cranbury, NJ: A. S. Barnes, 1976).

army helicopter at McCook Field. Construction of the helicopter first took place in a tin-roofed hangar and later relocated to an opened roof tent. Powered by a 220-horsepower rotary engine, the Flying Octopus weighed 3,600 pounds with the X-shaped structure being more than 60 feet wide, with four huge fan-shaped rotors mounted at each corner.[65]

De Bothezat first flew the helicopter at McCook Field in October 1922. During the 90 second flight, the craft rose six feet, drifted with the wind, and landed some 500 feet away. Over the next two years, the helicopter made more than 100 test flights—some rising to 15 feet and one with three passengers clinging to the frame to demonstrate the machine's stability. The first successful public demonstration of the helicopter took place on December 18, 1922, when the Flying Octopus reached an altitude of 30 feet. After testing the machine, the U.S. Army commented favorably but the machine's complexity and unreliability, as well as de Bothezat's unreliability, led the army to abandon the project. The rotary craft's failure to meet the standards initially set forth by the army led the chief of the Air Service to discontinue the project and the machine was housed in a hangar on base until it was eventually dismantled.[66]

The Development of the Autogiro

Juan de la Cierva and Harold Pitcairn licensed the Kellett Autogiro Corporation in Philadelphia to build autogiros for the U.S. Army. Kellett developed the YG-1, the first rotary-winged aircraft manufactured for and owned by the U.S. Army Air Corps, in 1935. It saw little service, however, with the U.S. military.[67]

On April 20, 1938, the U.S. Army established the first military Autogiro School in the country at Hangar 5, Patterson Field [Wright-Patterson Air Force Base], in Dayton, Ohio. The school trained officers as autogiro pilots and enlisted men as mechanics for autogiros. Initially, the training fleet consisted of three brand new YG-1B direct control autogiros. It eventually grew to include a total of seven autogiros, the largest collection at any location during that time. The four-week course was held in Hangar 5 which served as a classroom and a workshop. A total of 12 officer pilots and 15 enlisted mechanics were trained during the first two sessions. They were subsequently dispatched to Fort Monroe, Fort Sill, and Fort Bragg to continue testing with the ground services. Cdr. Hollingsworth Franklin "Frank" Gregory, who would later be a major champion of the helicopter, served as one of three pilot instructors and as project officer for all of the army's rotary wing aircraft.[68]

During World War II, the Kellett Autogiro Corporation became a leader in rotary aircraft manufacturing for the U.S. military. The company has the distinction of being the first to have their autogiros accepted for development service trials in 1943 by the U.S. Army Air Force. However, Sikorsky helicopters replaced the autogiro as the U.S. Army's rotary wing aircraft.

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[65] Warren R. Young, *The Epic of Flight: The Helicopters* (Alexandria, VA: Time-Life Books, 1982), 40-41; Gregory, *Helicopter*, 24-26.
[66] Gregory, *Helicopter*, 24-26.
[67] U.S. Centennial of Flight Commission, "The Contributions of the Autogyro," http://www.centennialofflight.gov/essay/Rotary/autogiro/HE3.htm (accessed December 2, 2004).
[68] Lois E. Walker and Shelby E. Wickam, *From Huffman Prairie to the Moon: The History of Wright-Patterson Air Force Base* (Washington, DC: Government Printing Office, 1986), 265-66.

One of the last autogiros produced in the United States, the Kellett XO-60 was delivered to the U.S. Army Air Force in 1944.[69]

Although autogiros continued to be used, the problem of ground resonance limited their use. Ground resonance is when the rotor blades move out of sync with each other, causing the rotor disc to become unbalanced. If not corrected, serious damage can occur within seconds. This phenomenon happens when a shock, such as a hard landing, is conveyed to the rotor system. If the center of gravity moves from the center of rotation, the entire vehicle can become unbalanced. This problem eventually led to the autogiro being replaced by the modern helicopter.[70]

Conclusion

The inter-war years had begun with a wide gap between American and European military aviation technology. Determined to erase this gap, the federal government, in particular the military, poured funding into aviation research. The impact of this funding was widespread. New aircraft designs made planes sleeker, more efficient, and able to fly greater distances. With the modern aircraft of the late 1920s, the army developed a distinctive doctrine for their deployment. In the 1930s, they began to acquire the mission, organization, and aircraft necessary to become an efficient fighting force. The navy experienced a similar pattern. Its aircraft carriers and corresponding aircraft allowed them to develop a doctrine and operations techniques. Both services gained greater bureaucratic influence, more pilots received training, and the military increasingly saw airpower as central to warfare. By the time of America's entry into World War II in 1941, the United States was a dominant force in military aviation technology.

[69] Smithsonian National Air and Space Museum, "Kellett XR-8," http://www.nasm.si.edu/research/aero/aircraft/kellett _xr8.htm (accessed March 10, 2005); Smithsonian National Air and Space Museum, "Kellett XO-60," http://www.nasm.si.edu/research/aero/aircraft/kellett_xo60.htm (accessed March 10, 2005).
[70] U.S. Centennial of Flight Commission, "The Contributions of the Autogyro."

PART FOUR: WORLD WAR II, 1939-1945

Crowds swarm the Wright Field flight line at an Open House held during World War II. Displays included captured foreign aircraft as well as nearly every type of Army Air Forces aircraft, including experimental types. Source: Aeronautical Systems Center History Office, Wright-Patterson Air Force Base

12. MILITARY AVIATION & WORLD WAR II, 1939-1945

> *[T]he conclusion is inevitable that our existing [air] forces are so utterly inadequate that they must be immediately strengthened.*[1]
>
> *—President Roosevelt's message to Congress, January 12, 1939*

In the years before World War II, President Franklin D. Roosevelt called for a drastic build-up in aircraft production. Two years before the United States entered the war, in response to the rising military crisis in Europe, Roosevelt specified a 10,000-plane air force. But in the spring of 1940, with the fall of France eminent and Britain's ability to withstand a Nazi blitz doubtful, he appeared before a joint session of Congress. There he announced the goal of building 50,000 planes per year (36,500 for the army and 13,500 for the navy), an astronomical number since manufacturers had produced only 2,141 military airplanes in 1939.[2]

The attack on Pearl Harbor accelerated this unprecedented arms build-up. Suddenly and simultaneously, the military aviation program needed to not only provide aircraft to its allies, but also produce its own equipment, aircraft, bases, and manpower. Technological innovations of the 1930s mandated a drastic increase in the creation and training of aircrew and ground crew, the improvement of airfields, and the development of new and superior aircraft.

MANUFACTURING

"What enabled President Roosevelt to ask for a 50,000-aircraft program [in 1940]," states one historian, "was the fact that since 1938 the Allies had ordered $500 million worth of aircraft, and thus the American factories were geared up."[3] Prior to 1939, Great Britain and France, had both become alarmed by the growing aggression of Nazi Germany, and they placed significant orders for American-produced aircraft from Northrop, Vought, Martin, and Curtiss. Following Germany's invasion of Poland in 1939, Britain and France increased their existing orders. After France's defeat in 1940, Great Britain not only took over French contracts with American manufacturers in the United States, it also increased its own commitments. By the autumn of 1940, American aircraft factories had contracts to supply the Royal Air Force with 14,000 American planes and 25,000 engines, representing a value of $1.5 billion. Adoption of the Lend-Lease program in 1941 further stimulated the production of military aircraft; and following Hitler's invasion of the Soviet Union in June of that year, the American government extended Lend-Lease deliveries to the U.S.S.R.

Expanding to meet the Industrial Demand

The repeated demands for more aircraft sparked a need for larger facilities and often aircraft factories simply expanded within their existing locales. At the time, the highest concentration of these factories was on the east and west coasts, although facilities in the Great Lakes area also

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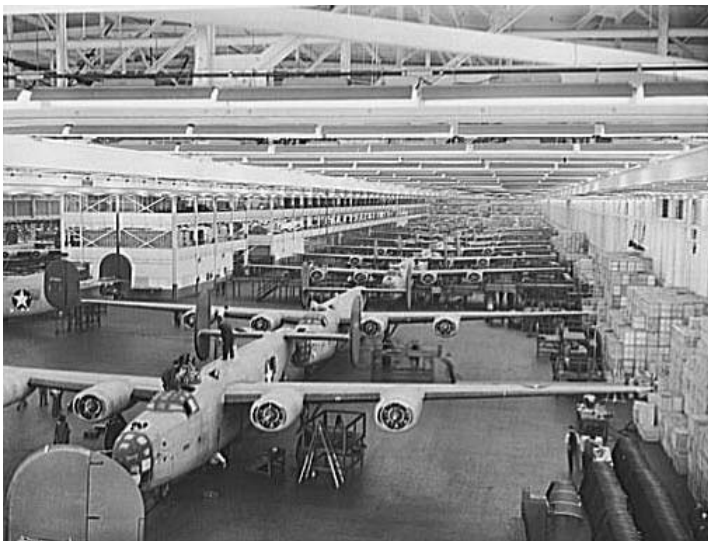
[1] Quote in Roger E. Bilstein, *The American Aerospace Industry: From Workshop to Global Enterprise* (New York: Twayne Publishers, 1996), 67.

[2] Donald M. Pattillo, *Pushing the Envelope: The American Aircraft Industry* (Ann Arbor: The University of Michigan Press), 118, 200; Roger D. Launius and Janet R. Daly Bednarek, eds., *Reconsidering a Century of Flight* (Chapel Hill: University of North Carolina Press, 2003), 3. Roosevelt's call for 50,000 planes was for "an expansion to that capacity rather than immediate production of that quantity, so that the major short-term impact of the goals was psychological." Pattillo, 118.

[3] Robin Higham, *100 Years of Airpower & Aviation* (College Station: Texas A&M University Press, 2003), 111.

built thousands of aircraft. In Detroit, considerable teething troubles plagued the new Willow Run plant in Detroit erected by the Ford Motor Company. But after determining that aircraft simply required closer fabrication tolerances and involved complex assembly procedures, Willow Run ultimately turned out 6,792 Consolidated B-24 bombers.



Looking up one of the assembly lines at Ford's big Willow Run plant, where B-24E (Liberator) bombers were made in great numbers. Source: Library of Congress, Prints & Photographs Division, FSA/OWI Collection, LC-USE6-D-008798

Sometimes companies established production facilities in completely new areas where there was plenty of land for sprawling assembly sites and where workers could be recruited from a broad geographic region. This approach was often the case for manufacturers who held subcontracts for the manufacture of aircraft other than their own. The Glenn L. Martin Company, for example, continued to build its own B-26 medium bombers and seaplanes for the navy on the East Coast, but also had a role in "the largest and most important wartime aircraft program," producing the Boeing B-29 bombers.[4] Near Omaha, Nebraska, Martin moved into a new plant that employed over 13,000 people (including over 5,000 women); this assembly line delivered the B-29 Superfortress eventually christened Bockscar (also known as "Bock's Car") which dropped the second atomic bomb on Nagasaki, Japan.

The need for higher production prompted manufacturers and the government to locate many new plants in regions where a workforce could be easily recruited and land was less expensive. Wartime factories were constructed near urban complexes such as the Dallas–Fort Worth area. Consolidated (Lockheed-Martin Aeronautics Company), for example, continued to build aircraft in its older factories around San Diego, but the company needed space to locate additional production capacity, especially for its B-24 bomber designed for the Air Corps in 1939. In Fort Worth, Consolidated purchased a huge plot of land at bargain prices. Wartime propaganda photos showcased the factory subsequently built with corporate and federal funds. When finished, the foundation of Air Force Plant 4 ran nearly one mile from end to end; B-24 bombers on an equally long assembly line seemed to stretch into infinity.

By the end of the war, American aviation manufacturers had delivered 324,750 aircraft from Piper Cubs (used for primary training and liaison service) to the B-29s. The industry also equipped these planes with some 812,000 engines. This output, within a relatively short time span, represented a stunning acceleration of production capacity. Official postwar assessments concluded that the momentum created by overseas orders in the years preceding the war pushed

[4] Quote, Pattillo, *Pushing the Envelope*, 109.

American production ahead by a full year, thus allowing U.S. manufacturers to reach maximum wartime efficiency much faster. This accelerated output stemmed from both traditional industrial mass-production techniques and fairly stable labor relations created by a largely successful no-strike pledge. A stable supply of critical materials and America's distance from the war theater also helped to ensure an accelerated output.[5]

TRAINING

As aircraft expansion programs grew in number, so too did the need for pilots, aircrew, and training facilities. Civilian flight and technical training schools, new military airfields, and existing civilian fields all participated in the national emergency. Technological innovations of the 1930s now required completely new training on a massive scale as trained navigators became radar navigators and bombardiers trained on the complex Norden bombsight. Military training also expanded to include female and black pilots.

Airfields

Both the growth of isolationism as well as a strong reluctance to fund military projects in peacetime meant that little to no support had been provided for military air bases during the interwar period. By 1939, only 17 army air bases were in operation in the continental United States and just 4 depots. Not only had many of these been sorely neglected during the interwar years, but changing aviation technology also meant that these bases were often outdated.[6] Over the next four years, the nation embarked on the largest military expansion in its history and by 1943, 345 major airfield installations, 116 sub-bases, and 322 auxiliary landing fields dotted the landscape.[7] The bases were "built from scratch," hastily constructed on vacant land, and many erected within six months.[8] According to Gen. Henry H. Arnold: "It was not unusual to find a training field with dozens of planes flying above it, bulldozers on the ground finishing the earthwork, cement mixers turning out concrete for runways yet to be built, and men in the open still clearing the brush off what had been grazing land."[9]

Technological changes in aeronautics required improvements in airfield design and construction techniques. New designs led to better use of existing space and more efficient servicing of aircraft, as well as steady improvements in the power and size of heavy-construction and earth-moving equipment. Airfield builders also incorporated advances in lighting, fueling systems, navigation aids, and other equally indispensable improvements during these years.[10] These new airfields initially incorporated hangars, barracks, warehouses, hospitals, dental clinics, dining halls, and maintenance buildings. Later, libraries, officers' and enlisted men's clubs, base exchanges, swimming pools, and sports fields were completed. Buildings were constantly improved throughout the war to make living more comfortable and training more efficient.[11]

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[5] Ibid., 148.
[6] Lou Thole, *Forgotten Fields of America: World War II Training Bases Then and Now* (Missoula, MT: Pictorial Histories Publishing Company, 2003), 3:153. The earliest airfields were simply cow pastures, fairgrounds, racetracks, parade fields, and polo grounds that did double duty as landing fields. Jerold E. Brown, *Where Eagles Land: Planning and Development of U.S. Army Airfields, 1910-1941* (New York: Greenwood Press, 1990), 2.
[7] Thole, *Forgotten Fields of America*, 3:153.
[8] Frederick J. Shaw, ed., *Locating Air Force Base Sites: History's Legacy* (Washington, DC: Air Force History and Museum Programs, 2004), 36; Thole, *Forgotten Fields of America*, 3:1.
[9] Thole, *Forgotten Fields of America*, 3:1
[10] Brown, *Where Eagles Land*, 2, 5-6, 8.
[11] Because concrete and steel was needed elsewhere as part of the war effort, most of the construction was of wood,

As part of this expansion of facilities, hard-surface runways were also needed. Before the Boeing B-17 multi-engine heavy bomber, created in the mid-1930s, became widespread, hard-surface runways were rare. But by 1942, hundreds of thousands of square yards of concrete blanketed scores of airfields across the United States. However, concrete was not always suitable for the rough terrain on which many new airfields were being hastily constructed. Moreover, it was in short supply during the war. Although asphalt was not as supportive or substantial as concrete or soil cements, the Air Engineers, a special engineering unit organized to construct and maintain airfields for the Air Corps, now began substituting asphalt runways for concrete ones. After 1940, engineers successfully borrowed paving techniques that had been pioneered on the Pennsylvania Turnpike. Later still engineers developed a system of interlocking steel mats "light enough to be portable and laid by a crew of unskilled men in a reasonably short time." This new system permitted the rapid construction of fields on sites previously unsuitable for airfields.[12]

Civilian Pilot Training Program: Primary

President Roosevelt's insistence that money be spent only for aircraft hindered practical training programs for the Air Corps. But Gen. Arnold, an ardent advocate of increased airplane production, insisted that building planes was of no use without pilots and aircrews. And given the enormous number of planes to be built under the president's program, Arnold advocated "a ground force of about a million men."[13]

Because "the time and cost of constructing many new flying fields seemed prohibitive," Arnold resolved to use civilian schools for primary (or elementary) pilot training.[14] He persuaded several civilian schools to invest in the necessary facilities before Congress had even allocated funds to pay for them. Formally launched in 1939, the Civilian Pilot Training Program (CPTP) became "the first full-scale, federally funded aviation education program and one of the largest government-sponsored vocational education programs of its time."[15]

Each civilian school fell under the supervision of one of three regional Air Training Centers activated by the Air Corps on July 8, 1940: Maxwell Field in Alabama (Southeast region), Randolph Field in Texas (Gulf Coast region, and Moffett Field in California (West Coast region). Primary school graduates then reported to military bases in the same region for basic and advanced training.[16] Carleton College [NR, 2003], near Northfield, Minnesota; Parks Air College, in Cahokia, Illinois; Embry-Riddle Aeronautical University, in Daytona Beach, Florida; the Spartan School of Aeronautics in Tulsa, Oklahoma; and the Ryan School in San Diego, California, were among the sites chosen to prepare the nation's future pilots.

At primary flight school, cadets followed the program developed at Randolph Field. During a ten-week course, cadets undertook ground school, military, and flight training. Using small,

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tarpaper, and non-masonry siding. Thole, *Forgotten Fields of America*, 3:1.

[12] Brown, *Where Eagles Land*, 135.

[13] James P. Tate, *The Army and Its Air Corps: Army Policy toward Aviation, 1919-1941* (Maxwell Air Force Base, AL: Air University Press, 1998), 175.

[14] Rebecca Hancock Cameron, *Training to Fly: Military Flight Training, 1904-1945* (Washington, DC: Air Force History and Museums Program, 1999), 320.

[15] Quote, Dominick A. Pisano, *To Fill the Skies with Pilots: The Civilian Pilot Training Program, 1939-1946* (Washington, DC: Smithsonian Institution Press, 2001), 3; Cameron, *Training to Fly*, 320.

[16] Cameron, *Training to Fly*, 315, 321.

uncomplicated airplanes with low horsepower, cadets negotiated four phases of flight training: handling the airplane; recovering from stalls and spins; landing; and executing certain maneuvers. Flight patterns were mastered in the second phase of training while the third phase was devoted to precision approaches and landing techniques. During the fourth "acrobatic" phase of training, students learned to perform difficult maneuvers such as loops or snap rolls. Nearly 40 percent of those accepted for primary flight training never became pilots.[17]

The CPTP began with the objective of training 300 pilots per year in 1939. This goal was increased to 7,000 per year in the spring of 1940 and then to 30,000 per year in 1941. By the time of Pearl Harbor, 41 primary schools were in operation. This number increased to 56 at the height of training in May 1943. Military service was optional under the terms of the program, but planners hoped that patriotism would motivate newly trained pilots to enlist. Within three years of its inception, CPTP had turned out an estimated 400,000 trainees.[18]

Naval Training

With its tradition of training its own pilots, the navy initially resisted using civilian flying schools for military training. But "this attitude…changed, when the navy realized that it could not turn out pilots in sufficient numbers to fight a two-ocean war without the CPTP's aid."[19] Beyond pilot training, in July of 1941, the chief of naval operations directed that additional gunnery and tactical training be added to the pilot-training programs established within the Atlantic and Pacific Fleets and Norfolk, Virginia, and San Diego [Naval Air Station San Diego], California. Advanced Carrier Training groups were instructed to indoctrinate newly designated naval aviators in the operation of current model carrier aircraft and to assign a number of patrol squadrons in each fleet the primary task of providing familiarization, indoctrination, advanced gunnery, and tactical training for new flight crews.[20]

In February 1942, the secretary of the navy announced that training for all prospective naval aviators would begin with a three-month course emphasizing physical conditioning. In May of that year, training began at the University of North Carolina and the University of Iowa. One month later, the University of Georgia and St. Mary's College, California, also offered this training, and by January 1943, twenty colleges and universities throughout the country provided fundamental training. Students at these schools then proceeded to the War Training Service courses conducted by the Civil Aeronautics Administration for two months of ground training. This was followed by three months of physical conditioning at pre-flight schools. Trainees were then ready for initial flight training at one of the navy's primary training bases.[21]

A sidelight to the development of a carrier fleet was the conversion of two luxury passenger, coal-burning steamers into the nation's first inland aircraft carriers. The navy commissioned the USS *Wolverine* in August 1942, and the USS *Sable* the following year, creating "the only side-

[17] Cameron, *Training to Fly*, commentary 321, 328. After Pearl Harbor, the 12-week primary training course became a 10-week course. John C. McManus, *Deadly Sky: The American Combat Airman in World War II* (Novato, CA: Presidio Press, 2000), 21-22.
[18] Bernard C. Nalty, *With Courage: The U.S. Army Air Forces in World War II* (Washington, DC: Air Force History and Museums Program, 1994), 34; Roger E. Bilstein, *Flight in America: From the Wrights to the Astronauts*, 3rd ed. (Baltimore: Johns Hopkins University Press, 2001), 161.
[19] Pisano, *Fill the Skies with Pilots*, 87; Cameron, *Training to Fly*, 391.
[20] Deputy Chief of Naval Operations (Air) and the Commander Naval Air Systems Command, *United States Naval Aviation, 1910-1980* (Washington, DC: Government Printing Office, 1981), 109, 112, 121.
[21] Ibid., 109, 112, 121.

wheel propelled carriers in the U.S. Navy, and possibly the world." The majority of pilots who qualified for carrier duty and those serving as carrier landing signal officers and ground crews during World War II received their training from the decks of these two ships. Fitted with a 550-foot flight deck and capable of only a top speed of 20 knots, the ships "contributed to the winning war effort in World War II by training hundreds of pilots in basic carrier operations."[22]

Army Training of Pilots: Basic & Advanced

Because civilian schools provided primary flight training, or what some cadets referred to as "kite flying," the Air Corps could concentrate on providing military programs for basic and advanced flight. Pilot training was "long and tortuous" with preflight instruction that amounted to "little more than military indoctrination and hazing." This training was intended to provide pilots with the ability to engage in air-to-air combat, or dogfights; to perform strafing missions to destroy ground targets; and to conduct escort missions to protect American bombers from enemy fighters.[23]

Those who successfully completed primary training took another 10 weeks of basic training where cadets were transformed into military pilots. Initially this basic training took place at Randolph Field in the Gulf Coast Training Center. However, in the fall of 1940, the training centers in the Southeast and West, Maxwell Field and Moffett Field respectively, also began offering basic training. In 1941, Goodfellow Field near San Angelo, Texas; Cochran Field in Macon, Georgia; and the Tuskegee School for black pilots in Alabama joined these training schools.[24]

Basic training required pilots to master instrument flying, night flying, formation flying, navigation flying, and cross-country flying in high-powered basic training planes. In ground school, cadets took courses in navigation, weather, engine and airplane operations, and wireless telegraphy (also known as "buzzer classes"). Basic training also was the "determinative point in a pilot's career" as pilots were assigned a specialty before graduating. They could be classified as either single-engine or two-engine pilots, or assigned a noncombat role. Single-engine training generally led to fighter pilot training while two-engine pilots became bomber pilots. The pilot's preference, his physical size, and, most importantly, the needs of the military determined the pilot's assignment.[25]

Advanced flight school took 12 weeks and provided new pilots with specialized and very rigorous training. Cadets gained experience with pursuit aircraft, fighter aircraft, and navigation and instrument flying. Ground school included radio procedures, tactics, code, and military training. Prior to the attack on Pearl Harbor, Kelly and Brooks Fields in Texas conducted advanced training. By the time of Pearl Harbor, eight advanced schools intended to teach either twin-engine or single-engine were set to open. The Gulf Coast Training Center instructed pilots

[22] Rick Yorczyk, "In Search of Sunken Warbirds: A Remote Sensing Survey of Lake Michigan," NOAA Ocean Explorer Projects, http://oceanexplorer.noaa.gov/projects/04warbirds/welcome.html (accessed September 11, 2005); Global Security, "IX-6 Wolverine," http://www.globalsecurity.org/military/systems/ship/ix-64.htm (accessed September 11, 2005); neither ship survives: the *Wolverine* was broken up in 1976, the *Sable* in 1948. Paul Jordan, "Paddlewheeler Aircraft Carriers: A Synopsis of IX-64 'USS Wolverine' IX-81 'USS Sable,' April 19, 2001; Paddleducks: USS Wolverine & USS Sable, http://www.paddleducks.co.uk/forum/viewtopic.php?=90&sid=b582c8b8c706da779a86 (accessed September 11, 2005).
[23] Paul Eden, ed., *The Encyclopedia of Aircraft of WWII* (London: Aerospace Publishing, 2004), 144, 426.
[24] Cameron, *Training to Fly*, 325-26, 328.
[25] McManus, *Deadly Sky*, 19-21; Cameron, *Training to Fly*, 325-27, quote on 325.

at Kelly, Brooks, Ellington and a school in Victoria, Texas, the Southeast Training Center used Maxwell and Barksdale Field in Shreveport, Louisiana. The Western Training Center included a school in Stockton, California, and Mather Field. Due to the rarity of twin-engine aircraft, only Barksdale actually produced twin-engine pilots at first, but by the spring of 1942, ten schools conducted twin-engine training. Later, Craig Field, east of Selma, Alabama, built on city-owned land and leased to the federal government, began single-engine training. Here, thousands of pilots received advanced training, completing a 72-hour course that included cross-country flights, instrument and night flying, and training in ground and aerial gunnery at nearby Eglin Field [NR, 1988] in Fort Walton Beach, Florida.[26]

Training of African American Pilots: The Tuskegee Airmen

In 1939, there were only 125 licensed African American pilots in the country, a number indicative of both the military ban on blacks learning to fly and the expense of private flying lessons. Reflecting the national practice of racial segregation, the U.S. Army Air Corps refused to accept any of these African Americans into its ranks or to create separate units for black pilots.[27] However, during World War II, the Army Air Corps created an elite group of African American pilots known as the "Tuskegee Airmen."

An amendment to the National Defense Act by Congress in April 1939 required the Civil Aeronautics Authority (CAA), a civilian agency, to designate one or more civil air schools to train black pilots. Concerns about weather and space ruled out sites in the Chicago area while Jim Crow laws in the South appeared to pose an insurmountable obstacle to the creation of a program to train African American pilots there. But when a War Department order on January 9, 1941, called for the rapid organization of a "Pursuit Squadron (Colored)," Frederick D. Patterson, president of the all-black Tuskegee Institute in Tuskegee, Alabama, proposed the Tuskegee field to train pilots. On July 23, 1941, the Tuskegee Army Air Field was officially established.[28]

The story of the Tuskegee Airmen, the tremendous obstacles they faced in serving their country and their triumphs and accomplishments are reflected in the designation of the Tuskegee Airmen National Historic Site. The 332nd Fighter Group, which served with distinction as bomber escorts in combat in Italy, flew more than 1,500 sorties, destroyed 111 aircraft and one destroyer (sunk using a plane's machine gun). Its members received 150 Distinguished Flying Crosses. The 332nd Fighter Group's most important achievement, however, was "never losing a single bomber to enemy aircraft—the only escort unit with that record." On June 20, 1946, the field was deactivated. A total of 992 pilots had graduated from Tuskegee including 673 Single Engine School graduates, 252 Twin Engine graduates, 51 liaison pilots, 11 service pilots and 5 foreign pilots (from Haiti).[29]

[26] Cameron, *Training to Fly*, 329-30, 400. Over a thousand British cadets also earned their wings at Eglin. Thole, *Forgotten Fields of America*, 130-31.
[27] Pamela Feltus, "The Tuskegee Airmen," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Air_Power/Tuskegee/AP26.htm (accessed March 18, 2004).
[28] Brown, *Where Eagles Land*, 130; John L. Frisbee, *Makers of the United States Air Force* (Washington, DC: U.S. Government Printing Office, reprint 1996) 232-33.
[29] Quote, Feltus, "The Tuskegee Airmen"; Thole, *Forgotten Fields of America*, 3:19.

Training of Women Pilots: The WASP

Two women, Jacqueline "Jackie" Cochran and Nancy Harkness Love, were most responsible for the creation of a women's flying program during World War II. An accomplished air racer, who won the 1938 Bendix Trophy and two-time winner of the Harmon Trophy, the highest award given to an American aviator, Cochran was one of the most visible women pilots of the time.[30] Even before the attack on Pearl Harbor, she approached officials in Washington with a plan to train women pilots for the military but her proposal was dismissed. She then organized a group of America's most experienced women pilots to serve in the British Air Transport Auxiliary. Like Cochran, Nancy Harkness Love, who had run a successful aviation company in Boston with her husband, was also an accomplished pilot. Working for the Air Transport Command (ATC) in Washington, she advocated the use of women pilots for ferrying duties early on.

Faced with a critical shortage of pilots, the ATC took up Love's cause and announced the formation of the Women's Auxiliary Ferrying Squadron (WAFS). Female recruits had to have a commercial pilot's license with a 200-horsepower rating and more than 500 hours of flight time, be between the ages of 21 and 35, and be at least 60 inches tall. Twenty-five women met those requirements and were hired as civilian employees at $250 per month ($50 less than male civilians hired for the same assignments).[31]

The Women's Flying Training Detachment (WFTD) training school was at Avenger Field in Sweetwater, Texas; this was the only field dedicated exclusively to training women pilots to fly America's military aircraft. At Avenger Field, 1,074 women underwent all three phases of military flight training (primary, basic, and advanced). This training "paralleled but did not duplicate" the training given to men. Because the WFTD's primary mission was to ferry aircraft, emphasis was placed on cross-country flying; gunner and formation flight training was omitted.[32]

In 1941, Col. Robert Olds, who headed the Air Corps Ferrying command, asked a War Department site board to select a field within 100 miles of the nation's capital that permitted extension of a hard-surface runway to 6,500 feet, was not already occupied by other Air Corps units, was free of light planes, and was available for a dollar per year. Olds also demanded at least 80 acres for housing.[33] New Castle, Delaware, met the criteria and, following an intensive screening process, the first WAFS arrived at New Castle Air Base [Hangar, New Castle Army Air Base] in October of 1942. This airbase, on the site of the New Castle County Airport near Wilmington, Delaware, was one of the first ferrying stations for transporting aircraft to England.

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[30] Janet R. Daly Bednarek and Michael H. Bednarek, *Dreams of Flight: General Aviation in the United States* (College Station: Texas A&M University Press, 2003), 81. By the time Jackie Cochran died in 1980, "she held more speed, altitude, and distance records than any other pilot, male or female, in aviation history. Her career spanned 40 years from the Golden Age of the 1930s as a racing pilot, through the turbulent years of World War II…into the jet age, when she became the first female pilot to fly faster than the speed of sound." Jackie Cochran and Maryann Bucknum Brinley, *Jackie Cochran: An Autobiography* (New York: Bantam Books, 1987), i.

[31] Anne Noggle, *For God, Country and the Thrill of It: Women Airforce Service Pilots in World War II* (College Station: Texas A&M University Press, 1990), 5.

[32] When the women began their training at Avenger Field, they found a class of male cadets training to be transport pilots. "The men remained at the field for about two weeks after the women arrived, resulting in the earliest coeducational flight training in the history of the American armed forces," Noggle, *For God*, 7.

[33] Pamela Feltus, "Women in the Military in World War II," U.S. Centennial of Flight Commission, http://wwwcentennialofflight.gove/essay/Air_Power/Women/AP31.htm (accessed March 18, 2004); Brown, *Where Eagles Land*, 134.

The United States relied heavily on the ATC, whose principal task was flying military aircraft across the Atlantic and Pacific for delivery to combat units. The WAFS first flew Piper Cubs and Fairchild PT-19 primary trainer aircraft, but they were soon ferrying "anything the Army Air Forces wanted moved." By January of 1943 the WAFS were split into four squadrons—one squadron remained at the New Castle base while others went to Dallas, Texas; Romulus, Michigan; and Long Beach, California.[34]

Upon hearing that Love would head the first group of women pilots to fly as civilians for the U.S. military, Cochran demanded that Gen. Arnold act on her earlier request to train women pilots. In August of 1943, Cochran became the head of the WFTD, which eventually merged with the WAF to form the Women Airforce Service Pilots (WASP). Initially, WASP were restricted to flying only primary training and liaison aircraft, but by the time the program was deactivated, WASP had flown every plane in the U.S. Army Air Forces' inventory.[35] In addition to ferrying aircraft, WASP tested new planes, towed aerial targets for gunnery practice using live ammunition, and served as instructors to hundreds of cadets.[36] Women aviators also simulated strafing, served as flight instructors, and ran check flights for recently repaired aircraft. Ann Baumgartner, working as a test pilot at Wright Field, became the first woman to fly the experimental YP-59 jet.[37]

Women paid their own way to go into training and, when disbanded, they paid their own way back home. More than 25,000 women applied to WASP but only 1,850 were accepted into training. Only 1,074 of those accepted for training earned their silver wings. "Housewives, mothers, debutantes, students, secretaries, beauticians, flight instructors, and even an actress and a movie stunt woman or two" were among those who joined WASP.[38] Thirty-seven WASP pilots died in service.[39]

By late 1944, with war in Europe nearing an end, male pilots, hoping to avoid being sent to the Pacific Theater, lobbied for the duties WASP were performing. On December 20, 1944, WASP was deactivated. The few former WASP who continued in the air force remained on the ground. Those who left the service and continued flying returned to the general aviation activities they had previously held.[40] Early efforts to militarize the WASP so that they would have veteran status and access to GI Bill benefits were denied. However, in March of 1979, Congress authorized the U.S. Department of the Air Force to consider WASP duty as "active military

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[34] Bilstein, *Flight in America*, 162; quote, Valerie Moolman, *Women Aloft* (Alexandria, VA: Time-Life Books, 1981), 147.
[35] Bednarek and Bednarek, *Dreams of Flight*, 82; Bilstein, *Flight in America*, 162. The correct plural of WASP is WASP. Because the acronym already stands for Women Airforce Service Pilots, adding an *s* is redundant. Many of the secondary sources quoted, however, insist on using the term "WASPs" and these references remain intact.
[36] Bilstein, *Flight in America*, 163.
[37] John L. Frisbee, "The WASPs of World War II," http://www.afa.org/magazine/valor/1195valor.asp (accessed June 26, 2005).
[38] "WASP Facts," http://www.wasp-wwii.org/wasp/facts.htm (accessed May 7, 2005); quote, Noggle, *For God*, 12.
[39] Although Janet R. Daly Bednarek and Michael H. Bednarek's book reports that 37 WASP died in service to their country, the majority of sources report 38 WASP deaths. Moolman, *Women Aloft*, 153. Of the 38 women who died while serving with the WASP, "none was more mourned than former barnstormer Evelyn Sharp…who died when she was thrown through the canopy of her P-38 as she crash-landed near Harrisburg, Pennsylvania. Since she was a civilian and did not qualify for death benefits, her fellow pilots took up a collection to help pay for her funeral. Although not officially entitled to do so, the townspeople of her hometown of Ord, Nebraska, draped her coffin with an American flag." Noggle, *For God*, 15.
[40] Bednarek and Bednarek, *Dreams of Flight*, 82.

service for the purpose of veterans' benefits," and the first honorable discharges were presented the following May.[41]

Training of Bombardiers

Sitting in the nose of the bomber, surrounded by clear Plexiglas, bombardiers were the most exposed of all the crew. Not surprisingly, they also experienced the greatest number of casualties of all aircrew members. Bombardier schools were quickly formed to address the need for combat-ready bombardiers but a lack of resources hampered training. General Arnold's 30,000-pilot program had originally called for 5,590 bombardiers, but within a month, the program had expanded and it now called for 14,000 bombardiers. By July of 1942 the 70,000-pilot program had created a need for 22,400 bombardiers to carry out war planners' commitment to strategic bombing.[42]

In July 1940, Lowry Field near Denver, Colorado, began training instructors in a ten-week course. The school graduated its first bombardier class in April 1941, and generated a curriculum. Barksdale Field in Louisiana began classes in May 1941, but the area's unsuitable hazy climate led to the school's closing in November. Training then moved to Ellington Field, near Houston, Texas, where one class graduated before the school moved to Albuquerque, New Mexico, for better climate.[43] In February 1942, a school opened in Midland, Texas.[44] Following formation of the Flying Training Command in 1942, new bombardier schools were established at Victorville, California (March 1942); Big Spring and San Angelo, Texas; and Hobbs, New Mexico (all in October 1942); Deming, New Mexico (December 1942); and Childress, Texas (February 1943).[45] Eventually thirteen schools, mostly in the southwest, trained bombardiers. In 1941, the total number of these graduates was 224, but by June of 1942, more than 1,400 had received training with a total of 52,495 receiving training before the end of the war.[46]

Training centered on the Norden bombsight. Although widely celebrated in the media for its contribution to the war effort, the bombsight's workings were kept secret. To protect this secrecy, bombardiers had strict orders to destroy the bombsights if shot down over enemy territory.[47] Describing the skill needed by bombardiers, Curtis E. LeMay, a former bomb group commander who would one day become Chief of Staff of the U.S. Air Force, noted that using a

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[41] Feltus, "Women in the Military"; quote, "WASP Facts"; Noggle, *For God,* 14. In March 2010, 300 of the remaining WASP were awarded the Congressional Gold Medal, the highest award Congress can award to a civilian. Previous recipients include the Tuskegee Airmen in 2006.

[42] McManus, *Deadly Sky,* 24; Stephen L. McFarland, *America's Pursuit of Precision Bombing, 1910-1945* (Washington, DC: Smithsonian Institution Press, 1995), 152-54.

[43] Cameron, *Training to Fly,* 342, 345, 347.

[44] McFarland, *America's Pursuit of Precision Bombing,* 152.

[45] Thole, *Forgotten Fields of America,* 2:53. Ellington Field near Houston, served as a bombardier training center for a short time but was later used for other types of training.

[46] McFarland, *America's Pursuit of Precision Bombing,* 152; Cameron, *Training to Fly,* 428.

[47] R. G. Grant, *Flight: 100 Years of Aviation* (New York: DK Publishing, 2002), 247; quote, Tom D. Crouch, *Wings: A History of Aviation from Kites to the Space Age* (New York: W. W. Norton, 2003), 390. Bombardiers were required to take the following oath: "Mindful of the secret trust about to be placed in me by my Commander in Chief, the President of the United States, by whose direction I have been chosen for bombardier training...and mindful of the fact that I am to become guardian of one of my country's most priceless military assets, the American bombsight...I do here, in the presence of Almighty God, swear by the Bombardier's Code of Honor to keep inviolate the secrecy of any and all confidential information revealed to me, and further to uphold the honor and integrity of the Army Air Forces, if need be, with my life itself." U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/ Dictonary/NORDEN_Bombsight/DI145.htm (accessed June 22, 2005).

bombsight was **"**very exacting precision work, requiring a great deal of care even under the best of circumstances…. Even with the Norden bombsight, the bombardier [must] still…see the target and identify it."[48] Despite these difficulties, the Norden bombsight enabled U.S. military strategists to engage in daylight precision bombing. Flying deep into enemy territory and within range of antiaircraft guns, bombardiers inflicted substantial damage on the military infrastructure and manufacturing facilities of the Axis war machine.

Training of Navigators

Navigators "acted as the eyes and ears of a bomber crew, pointing the pilot in the proper direction and keeping a log on any observed activity outside the aircraft."[49] The Air Corps had provided instruction in aerial navigation since the early 1930s, but existing schools could not meet the increased demand for trained navigators. "[T]he bombardment mission lay at the heart of an air force turning towards combat. Consequently the Air Corps needed navigators for the medium to heavy bombardment and attached reconnaissance squadrons that were scheduled for activation."[50]

Like primary pilot training programs, the Air Corps turned to civil aviation schools to train navigators until the expanded army schools could begin operating. Beginning in August 1940, at its facility in Coral Gables, Florida, Pan American Airways instructed student navigators under the supervision of the Southeast Air Corps Training Center. More than 50,000 students mastered an 18-week curriculum that included a variety of navigation techniques, including dead reckoning (navigating by way of compass headings and elapsed time), celestial navigation (using stars as a guide), and radio navigation (using radio signals received from ground stations). The Air Corps selected Barksdale Field, where twin-engine equipment was available, as its first navigation school. Training at Barksdale began in November 1940, but, once again, Louisiana's hazy climate closed the school in July 1941. Instruction in the Southeast Center moved to Turner Field in Georgia. In August 1941 training in the West Coast Center commenced at Mather Field and in the Gulf Coast Center at Kelly Field.[51]

Conclusion

During the expansion years between 1939 and 1941, the army built up its forces. But the declaration of war in 1941 meant raised quotas as training schools spread throughout the three Flying Training Commands. Training for pilots reached its high point in late 1943, and training for navigators and bombardiers hit its peak nearly a year later. Ten civilian flight schools operated at the end of 1944, two on V-J Day, and none by the end of the war.[52]

[48] McManus, *Deadly Sky*, 31-32.
[49] Ibid., 24.
[50] Cameron, *Training to Fly*, 337.
[51] Cameron, *Training to Fly*, 340; George M. Watson, Jr., "Building Air Power," in *Winged Shield, Winged Sword*, ed. Bernard C. Nalty (Washington, DC: Air Force History and Museums Program, 1994), 1:260.
[52] Cameron, *Training to Fly*, 384, 391, 415, 448.

MUNICIPAL AIRPORTS IN WARTIME

Airport Improvements

Once the United States entered World War II, the army, navy and the U.S. Army Air Forces (USAAF) utilized civilian airports around the country. In some cases they leased these airports entirely, in others they purchased private airports, or, in still others, they arranged for municipal airports to function as air bases during the war with the promise of returning them to civilian use following the end of hostilities. As early as August 1939 the War Department directed the Office of the Chief of the Air Corps to create a list of airports that, with improvements, could be of military value. The list—a product of consultations between the army, the navy, the Works Progress Administration (WPA) and the CAA, with the secretary of war—soon grew to include approximately 4,000 airports throughout the continental United States and its possessions. Proposed spending was $560 million over six years, a figure that caused Congress to balk. Though the plan clearly delineated the military value of the airports, the United States was not yet at war in 1940. In October 1940, however, Congress created a more modest program for improvements at 250 airports.[53]

The new program was known as the Development of Landing Areas for National Defense (DLAND). This was the first time Congress appropriated money for the CAA to use on airport improvements. With the army and navy, the CAA pared the list down to 200 publicly owned airports. To participate in the program, the political subdivision owning the airport had to agree to "make it available to the Federal Government without cost, and further pledge itself to maintain and operate the improved airport."[54] Although often described as a national airport program, most of the funding went to the east and west coasts, and the South. An October 1941 article in *Aero Digest*, for example, listed the number of airport improvement projects under way by state. Florida led all states with 31 projects at a cost of $15 million. California came in second with 17 projects ($8.3 million) and Maine was third with 16 sites ($7.2 million). Other states with numerous projects included Texas (15), Washington (12), and Massachusetts (10).[55]

DLAND received the last of its congressional appropriations in May 1942. The following year, Congress abolished the WPA and $1 million earmarked for airports transferred to the CAA. Although the WPA recommended that the army and the navy finish projects already underway, ongoing projects were suspended. The War Production Board, established by executive order in January 1942 to direct war production and the procurement of materials, simultaneously recommended canceling 42 CAA-sponsored airport projects. Although both the CAA and the military protested that decision, only 11 of those projects saw completion. In 1944, Nebraska congressman Karl Stefan sponsored an amendment to a war appropriation bill to complete the suspended WPA projects. Congress approved, appropriating $9.7 million under a new program known as the Development of Civil Landing Areas (DCLA).[56]

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[53] Ibid., 21-22; "4000 Airports for U.S. Envisioned under New Plan," *Aero Digest* 37 (October 1940): 161; "200,000,000 Worth of Airports," *Western Flying* 20 (September 1940): 18-20.

[54] "CAA Forging Ahead on Airport Program," *Aero Digest* 37 (December 1940): 74; see "200 Airports in New CAA Program," *Aero Digest* 38 (January 1941).

[55] "278 Defense Airports under Construction," *Aero Digest* 39 (October 1941): 87. For more on the regional nature of the program see "Large-Scale Improvement Program Modernizes Strategic Airports," *Aero Digest* 39 (September 1941): 88, 90, 94, 98, 260; "Recent Improvements in Airports Vital to Defense," *Aero Digest* 39 (December 1941): 77-78, 81-82, 166.

[56] John R. M. Wilson, *Turbulence Aloft: The Civil Aeronautics Administration amid Wars and Rumors of War, 1938-1953* (Washington, DC: U.S. Department of Transportation, Federal Aviation Administration, 1979), 110-13.

Besides DLAND, the arrival of military forces brought improvements to municipal facilities. Atlanta's municipal airport for example, received DLAND funds in 1941 to extend two existing runways and build two new runways. After Pearl Harbor, the army leased the section of the field used by the military and renamed it Atlanta Army Air Field. By 1944, the army had spent $1.4 million improving the field.[57] At the Milwaukee County Airport [now General Mitchell Airport], DLAND funds helped extend runways and improve lighting and drainage systems. In April 1942, the USAAF selected this airport to host the 10th Carrier Group and the military funded further improvements to the runways and built barracks for the troops. Under military management, the renamed Billy Mitchell Field received additional improvements, including a wider airplane parking apron, an officers' club, and a 75-bed hospital.[58]

Air Traffic Control

On the eve of the United States' entry into World War II, the CAA also began to extend its air traffic control responsibilities to takeoff and landing operations at airports. This expanded role eventually became permanent after the war.[59] President Roosevelt authorized the secretary of war "to take possession and assume control of any civil aviation system, or systems, or any part thereof, to the extent necessary for the successful prosecution of the war." The secretary of war requested that long-term CAA projects for commissioning airway traffic control centers and completing the phone and teletype network "be expedited to the fullest extent possible in the interest of National Defense." The army and navy then identified airports essential to national defense. Ultimately, the CAA took over operation of more than 50 airport control towers and greatly expanded the en route air traffic control system. In 1941, the First Supplemental National Defense Appropriation Act allocated funds for the CAA to construct, operate, and maintain airport traffic control towers. In 1944, CAA-operated airport traffic control towers peaked at 115 towers. After 1945, War Department funds underwriting the CAA's airport activities decreased as the military use of civil airports declined. The CAA then returned some airport control towers to local jurisdictions.[60]

[57] U.S. Air Force, History Support Office, Bolling Air Force Base, *History of the Atlanta Army Air Base Army Airport, Atlanta, Georgia, 1939 to Dec. 7, 1941* (Washington, DC, 1944), 2-11; U.S. Air Force, History Support Office, Bolling Air Force Base, *History of the Atlanta Army Air Base Army Airport, Atlanta, Georgia, Part II (Covering the Period 1939 to 7 December 1941)* (Washington, DC, July 13, 1942), 2-12; Betsy Braden and Paul Hagan, *A Dream Takes Flight : Hartsfield Atlanta International Airport and Aviation in Atlanta*, (Athens : University of Georgia Press, c1989), 112-14.

[58] Michael J. Goc, *Forward in Flight: The History of Aviation in Wisconsin* (Friendship, WI: Wisconsin Aviation Hall of Fame and New Past Press, 1998), 142-43; U.S. Air Force, History Support Office, Bolling Air Force Base, *Brief History of Billy Mitchell Field, Milwaukee, Wisconsin, to 31 August 1944* (Washington, DC), 4-10, 18-21; U.S. Air Force, History Support Office, Bolling Air Force Base, *History of Billy Mitchell Field, Milwaukee, Wisconsin, 1 January 1945 to 16 January 1945*, compiled by Harold Moffett (Washington, DC), 30-31.

[59] Edmund Preston, "The Federal Aviation Administration and Its Predecessor Agencies," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Government_Role/FAA_History/POL8.htm (accessed June 27, 2005).

[60] Federal Aviation Administration, "FAA Historical Chronology."

RESEARCH & DEVELOPMENT

During the war years, NACA research became almost exclusively focused on military applications. NACA facilities, like those of other military test centers beyond Wright Field, expanded across the country. One important aeronautical innovation taking place outside laboratories and wind tunnels during this era was helicopters. Igor Sikorsky produced the first practical helicopter in 1939, and the Coast Guard took the lead in its potential use in anti-submarine warfare and its search and rescue capabilities. Even so, the helicopter did not become a mainstay with U.S. armed forces until after the war.[61] Other important innovations included radar development and cold weather flying.

NACA and Wright Field

In 1940, NACA established two new laboratories: Ames Laboratory adjacent to Moffett Field near San Francisco, and Lewis Laboratory in Cleveland. Ames was the West Coast counterpart to Langley while Lewis conducted engine research. Rather than advancing aeronautical knowledge during the war years, NACA concentrated on making refinements and creating solutions to specific problems. One specific outstanding achievement came from Eastman Jacobs's efforts at perfecting the laminar-flow airfoil in the late 1930s and early 1940s. Using a low turbulence wind tunnel at Langley, Jacobs "solved the problem of draft-inducing turbulence at the wing trailing edge that had restricted aircraft performance." The highly successful North American P-51 Mustang fighter plane became the first aircraft to use this foil.[62]

The military was responsible for testing new techniques that eventually shaped the production lines, and wartime production required rapid integration of technologies that had evolved from combat experience. For the USAAF, Wright Field became a leading research-and-development center for new technologies that encompassed evaluation and testing as well as conceptual proposals for entirely new aircraft. At Eglin Field in the Florida Panhandle, 724 square miles of land area and an additional 86,500 square miles in the Gulf of Mexico provided an essential proving ground to test weapons and aircraft under a wide range of potential combat environments. The Naval Air Test Center, along the Patuxent River in Maryland, as well as the facilities at the Point Mugu Naval Air Weapons Station, near Oxnard, California, became similar sites for U.S. Navy and Marine Corps aviation development. All the services used the convenient landing facilities that characterized Muroc Army Air Field, located in the desolate desert region northwest of Los Angeles. Rogers Dry Lake [NHL, 1985], a vast expanse of hardened desert surface, provided a unique area that facilitated unscheduled landings by occasionally unreliable test aircraft.[63]

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[61] Gross, *American Military Aviation*, 99-100.

[62] Pattillo, *Pushing the Envelope*, 118, quote on 128-29.

[63] For overviews of wartime manufacturing, see John B. Rae, *Climb to Greatness: The American Aircraft Industry, 1920-1969* (Cambridge: MIT Press, 1968), 141-72; Bilstein, *Enterprise of Flight*, 63-78; Alfred Goldberg, ed., *A History of the United States Air Force* (New York: Arno Press, 1974), 47-51, 91-93; Jacob Vander Meulen, *The Politics of Aircraft: Building an American Military Industry* (Lawrence: University Press of Kansas, 1991), 117-224. For a comprehensive and detailed analysis, see Irving Brinton Holley, *Buying Aircraft: Material Procurement for the Army Air Forces* (Washington, DC: Government Printing Office, 1964). This source is part of the official war history series, *The United States Army in World War II*, Special Studies, no. 7. On the role of women, see Juanita Loveless, ed., *Rosie the Riveter* (Long Beach: California State College, 1983), especially 259-70.

Cold-Weather Flying

General Arnold was one of the first to recognize the value of establishing a cold-weather test station to experiment in adapting planes, personnel, equipment, and base facilities to operate successfully in deep cold temperatures. He was instrumental in persuading the War Department to establish Ladd Field [NHL, 1985] 3.5 miles east of Fairbanks, Alaska, for these purposes. Here vital lessons were learned about wing-icing, navigation, aircraft maintenance and operation, instruments and controls, and radio investigations for operating aircraft in arctic-like conditions. As the Japanese prepared to invade the Aleutians in 1942, the Eleventh Air Force established an Air Depot at Ladd Field for the repair, testing, and supply of aircraft in the Alaska Theater. The first troops arrived in April of 1940 and, beginning in 1942, Ladd Field became the center of the "ALSIB [Alaska/Siberia] Movement," wherein nearly 8,000 military aircraft from the United States were transferred to Russian aircrews for use on the Russian Front. An early experiment resolved the best way to construct a 5,000-foot runway that would not buckle in freezing and thawing conditions. Two feet of topsoil were removed. Concrete, reinforced with steel, was then poured over a base of one foot of unwashed gravel, providing a successful alternative to blasting through frozen tundra.[64]

Rotary Flight[65]

"The development of the helicopter," according to one commentator, "ranks with the jet engine among the most significant aeronautical achievements of the Second World War. Although actively experimented with in several countries for years, wartime brought both developments to the operational stage, with consequent momentum for postwar applications. While lagging in jet engine development, in the helicopter field the United States was well ahead and would remain a leader."[66] The Coast Guard took the lead in developing the helicopter for anti-submarine warfare and search and rescue.

The federal government became interested in the helicopter in the late 1930s, and on June 30, 1938, the Dorsey Bill authorized $2 million for the development of rotary-wing and other aircraft.[67] An inter-agency board formed to implement the project. Among its members was Cdr. William J. Kossler, headquarters aviation engineering officer for the Coast Guard. "During the inter-agency board of 1938, the Navy asserted the helicopter was but a minor application and not worth pursuing."[68] Thus, the army issued specifications for bids in late 1939. Platt-LePage Aircraft Company and the Sikorsky Helicopter Plant both bid on the project. The army accepted the Platt-LePage proposal for the XR-1 (along with two contracts to Kellett for autogiros, the

[64] Erwin N. Thompson, "Ladd Field," National Register of Historic Places Inventory Nomination Form (Washington, DC: April 18, 1984), http://tps.cr.nps.gov/nhl/detail.cfm?ResourceID=1910&resource Type=District (accessed June 17, 2005).
[65] Portions of "World War II Era and the Development of the Helicopter" excerpted from Dwayne A. Day, "Helicopters at War," U.S. Centennial Commission, http://www.centennialofflight.gov/essay/Rotary/Heli_at_War/HE14.htm (accessed December 2, 2004), Day, "Igor Sikorsky—VS-300," and Dwayne A. Day, "Piasecki: The *Dogship* and the *Flying Banana*," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Rotary/Piasecki/HE4.htm (accessed December 2, 2004).
[66] Pattillo, *Pushing the Envelope*, 100, 141.
[67] Sergei Sikorsky, "The Dorsey Controversy," FindArticles.com, from *Flight Journal*, 2003, http://findarticles.com/p/articles/mi_qa3897/is_200304/ai_n9221889/ (accesssed August 9, 2010).
[68] First Lieutenant Andrew Conwell, "History of Coast Guard Rotary-Wing Aviation: From Inception to the Modern Day," U.S. Coast Guard, April 6, 2008, http://www.uscg.mil/history/articles/AndrewConwellCGRotorcraftHistory.pdf (accessed August 9, 2010), 4, 6.

XR-2 and XR-3). In the meantime, Sikorsky demonstrated its design and on December 17, 1940, the inter-agency board chose both the Sikorsky VS-300 and the XR-1.[69] During the early 1940s, Sikorsky established a temporary helicopter-training facility at the company's factory in Bridgeport, Connecticut.

In 1941, the Coast Guard was transferred to Navy Department control. Because the navy was preoccupied with fighting the war, Cdr. Watson A. Burton, commanding officer of Coast Guard Air Station Floyd Bennett Field in Brooklyn, felt the Coast Guard should take the lead in promoting the helicopter. To this end, he and Kossler traveled to the Sikorsky Helicopter Plant in Stratford, Connecticut, to attend the "first official American helicopter demonstration" on April 20, 1942. Impressed by what they saw, both men believed the helicopter could fill Coast Guard needs.[70]

Eventually Kossler managed to place Coast Guard Air Station Brooklyn's Executive Officer Lt. Cdr. Frank Erickson at a helicopter demonstration. Erickson already had an interest in rotary flight. On December 7, 1941, he had watched helplessly from a control tower as Japan bombed Hickam Field growing frustrated over his inability to save any of the thousands killed or wounded. Having read about a rotary-winged machine being developed by Igor Sikorsky, he believed it could play a role in Coast Guard search-and-rescue operations. Following the demonstration, Erickson wrote Coast Guard Commandant Vice Adm. Russell R. Waesche of the helicopter's potential value in search and rescue and law-enforcement. More importantly, because antisubmarine warfare against German U-boats had become a major concern for the American military during the early stages of the war, he emphasized its potential for convoy protection against German U-boats. On February 19, 1943, the German U-boat threat convinced Adm. Ernest King, chief of Naval Operations, to assign "development of the helicopter for anti-submarine warfare (ASW) to the Coast Guard," and he "ordered a Combined Board for the Evaluation of the Helicopter in Anti-Submarine Warfare."[71]

Kossler chose Erickson to be the Coast Guard's first helicopter pilot. Erickson received flight instruction at Sikorsky's training facility, graduating in the spring of 1943.[72] Meanwhile, Adm. King delineated a Coast Guard program to test, evaluate, and develop the helicopter. Eventually the helicopter training facility transferred from the Sikorsky factory to Coast Guard Air Station Brooklyn [Floyd Bennet Field Historic District, NR, 1980].[73] On November 19, 1943, this station was officially designated as a helicopter training base and tasked with the responsibility of developing the helicopter while also training the necessary mechanics. The Coast Guard now controlled all helicopters flying for the navy with the exception of those flying out of other navy test facilities, such as the Air Test Center at Patuxent River. Ultimately, the army provided the Coast Guard with the service's first helicopter, a Sikorsky VS-300 (HNS-1).[74]

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[69] Sikorsky, "Dorsey Controversy."
[70] Browning, *Eyes and Ears of the Convoy*, 2-3, 5.
[71] Conwell, "History of Coast Guard," 5, 7.
[72] Ibid., 9.
[73] Browning, *Eyes and Ears of the Convoy*, 8; U.S. Coast Guard, "Floyd Bennett Field Air Station Brooklyn," U.S. Coast Guard Historian's Office, http://www.geocities.com/floyd_bennett_field/uscg.html?200526 (accessed April 26, 2005); the Vought-Sikorsky Division was transferred to a new facility in Bridgeport, Connecticut, in 1942 when the facilities in East Hartford, Connecticut, proved inadequate to the demands of helicopter production, which required separate facilities and organization. Connecticut Air and Space Center, "Vought-Sikorsky and Change Vought Aircraft: The Stratford Year, April 1, 1939 to December 31, 1948," http://www.ctairandspace.org/vought.html (accessed June 23, 2005).
[74] Browning, *Eyes and Ears of the Convoy*, 2-3, 5.

Anti-Submarine Warfare

In June of 1942, the navy had suffered devastating losses to German U-boats, losing one in 20 ships crossing the Atlantic. Anti-submarine warfare became the focal point for the World War II Coast Guard helicopter. The Combined Board first considered whether the HNS-1 could sink submarines with a depth charge. The HNS-1 could only carry one depth charge at a time, which caused insignificant damages to submarines. The helicopter would, the committee decided, best serve as an observation platform above a convoy where it could spot submarines but not be easily detected through a periscope.[75]

To test the helicopter as an anti-submarine warfare weapon, the Combined Board chose a three-tier training program that would ready pilots for convoy work. The first tier began with flat-water trials, the second moved to the open seas, and the third operated from ships crossing on an Atlantic convoy. For the first tier, both Erickson and Kossler secured the cargo ship USS *Bunker Hill* (CV-17) moored near the airfield off Stratford Point, Long Island Sound, to test the helicopter. On May 7, 1943, Col. H. Franklin Gregory, who was charged with overseeing helicopter development for the army, successfully completed 20 flights off the tanker. This proved the helicopter could land on a small strip of deck only 78 feet in length.[76]

The second tier open sea trials began aboard the U.S. Coast Guard cutter *Cobb*. The Coast Guard acquired the *Cobb* from the War Shipping Administration and converted it from a coastal passenger ship to the first helicopter carrier.[77] In June 1944, in the Long Island Sound, Erickson made the first shipboard helicopter landing on the deck of a moving ship. The Combined Board was now ready to move to the final trial tier.[78]

In July 1944, the USS *Daghestan* with the HNS-1 helicopter on board joined a North Atlantic convoy traveling from New York to Liverpool, England. On its tenth day at sea, Coast Guard Commander Stewart Ross Graham, who had become Coast Guard Helicopter Pilot No. 2 after being trained by Erickson at Sikorsky, flew 30 minutes around the convoy marking the first helicopter lift off and landing on a ship at sea. During three days of trials, American pilots made 166 takeoffs and landings on the *Daghestan's* flight deck which measured 50 by 96 feet; British pilots completed 162 landings. The tests proved that the helicopter could function in 40 mile per hour winds if a wind screen was used to start and stop the rotor blades. The "HNS-1's performance was

The first successful helicopter take-off and landing while on convoy at sea on the USS *Daghestan. Source: United States Coast Guard Historian's Office, http://www.uscg.mil/hq/g%2Dcp/history/bio%5Fstewart%5Fgraham.html*

[75] Conwell, "History of Coast Guard," 7, 10.
[76] Browning, *Eyes and Ears of the Convoy*, 30.
[77] Modifications to the vessel's structure included a new engine and a complete overhaul of the upper works through the cutting down of the superstructure, as well as the addition of a flight deck on the aft section measuring 38 by 63 feet, with a capacity to accommodate three helicopters. U.S. Coast Guard, "Cobb, 1944 WPG-181 (ex-*Governor Cobb*)," U.S. Coast Guard Historian's Office, http://www.uscg.mil/history/webcutters/Cobb1944.asp (accessed December 10, 2010).
[78] Conwell, "History of Coast Guard," 11.

[deemed] too marginal for an anti-submarine warfare mission and…it did not have enough power to follow the deck when the ship was pitching."[79] Coast Guard Commandant Waesche suggested that more tests should take place on the USS *Cobb* to fine-tune issues with the helicopter and to determine the effectiveness of new types of rotary-winged aircraft.

After the trials, Erickson suggested that the best role for helicopters would be to serve as the "eyes and ears of the convoy," by equipping them with radar and sound-ranging equipment for the detection of submarines.[80] In April 1944, testing to determine whether helicopters could be equipped with "dipping sonar," much like the ones used on blimps for antisubmarine hunting, commenced. A major concern in equipping helicopters with dipping sonar was the noise generated from the wash of the helicopter rotors. Testing undertaken on the *Cobb* dispelled this concern by demonstrating that the noise level from the rotors did not interfere with proper operation of the equipment.[81]

Search and Rescue

By July 1944, German U-boats no longer posed an ominous threat, and the development of helicopters for anti-submarine warfare was discontinued. The Coast Guard could now focus on the helicopter's potential for search-and-rescue situations. The helicopter's major role as a "flying ambulance" was foreshadowed by a rescue mission carried out by Commander Erickson on January 3, 1944. Erickson successfully piloted an HNS-1 helicopter through 25-knot winds to deliver much-needed plasma to survivors of an explosion on the destroyer USS *Turner*. Earlier that same morning magazine explosions aboard the *Turner* had caused multiple casualties. When the hospital in Sandy Hook, New Jersey, exhausted its blood plasma supply, Commander Erickson flew from U.S. Coast Guard Air Station Brooklyn to Battery Park to pick up the desperately needed plasma and ferry it to the hospital. Despite deteriorated weather conditions, he still landed on the hospital grounds a mere 14 minutes after leaving Battery Park. Following his dramatic delivery of medical supplies, Erickson became responsible for developing the Coast Guard's search-and-rescue activities and he went on to develop a majority of the rescue equipment including the hydraulic hoist which he developed jointly with Sikorsky.[82]

The helicopter also first demonstrated its superiority over conventional fixed-wing aircraft for search-and-rescue missions during World War II when four American Sikorsky helicopters were transported to India for trials. During the trials on April 23, 1944, Lt. Carter Harman of the USAAF piloted a Sikorsky YR-4 into Burma to rescue three downed airmen stranded behind Japanese lines.[83] This marked the first recorded instance of a rescue mission by helicopter behind enemy lines.[84] Despite the helicopter's limitations, military leaders realized that these aircraft were ideal for searching for downed airmen, sailors stranded at sea, and civilians. However, to carry out these searches, bigger helicopters with greater internal capacity and more powerful engines were needed.

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[79] Browning, *Eyes and Ears of the Convoy*, 13.
[80] Ibid., 10.
[81] U.S. Coast Guard, "Cobb, 1944 WPG-181 (ex-*Governor Cobb*)"; Browning, *Eyes and Ears of the Convoy*, 14-15.
[82] Browning, *Eyes and Ears of the Convoy*, 14; U.S. Coast Guard, "A History of Coast Guard Aviation," U.S. Coast Guard Historian's Office, http://www.uscg.mil/hq/g-cp/history/h_aviation.html (accessed May 24, 2005).
[83] Helicopter designations changed from X for experimental to Y for a service-test model. Warren R. Young, *The Epic of Flight: The Helicopters* (Alexandria, VA: Time-Life Books, 1982), 84.
[84] John Everett-Heath, *Helicopters in Combat: The First Fifty Years* (New York: Sterling Publishing Company, 1993), 15.

Piasecki

By 1947, over 70 companies in the United States were developing helicopters, but only a few of them would actually produce successful aircraft in large quantities. One of the early successes was Piasecki Aircraft (also known as Piasecki Factory Heliport) in Morton, Pennsylvania. By the age of 20, Frank Piasecki had earned degrees in aeronautical and mechanical engineering and, in 1940, with the support of a few friends, he started a small aeronautical company. Working out of a garage in Philadelphia, Piasecki built a single-person, single-rotor helicopter designated the PV-2 which test-flew in 1943. Piasecki realized that Sikorsky was the favored helicopter manufacturer for the U.S. Army, so he appealed to the U.S. Navy with his PV-2. Piasecki also had an idea for a much larger helicopter capable of fulfilling various naval missions, such as rescuing sailors at sea. Although navy leaders initially showed little interest in helicopters, Piasecki received a navy contract for a single new heavy-duty transport helicopter on January 1, 1944.[85]

Piasecki built a helicopter that had two rotors, one at each end of a long, somewhat cylindrical fuselage. The two rotors were easier to manufacture and control than a single large rotor, and the long fuselage could be loaded with cargo or people, alleviating concerns about even weight distribution. Piasecki's new tandem two-rotor craft, designated the PV-3, made its first flight in March 1945. The navy designated it the XHRP-X, but Piasecki employees referred to it as the "Dogship." The tandem-rotor configuration soon proved highly capable and after the war, Piasecki received a contract to build a military prototype.

Although helicopters remained limited by their power and size, World War II demonstrated that these aircraft could perform useful missions. Ordered to use helicopters in submarine warfare, the U.S. Coast Guard adopted the aircraft for search-and-rescue missions as well as scouting and searching for submarines. In the China-Burma-India Theater, the 1st Air Commando Unit used the craft for rescue operations. And in June 1945, helicopters airlifted at least 70 wounded soldiers from the front lines on the island of Luzon in the Philippines, to rear-area hospitals, marking the first time that U.S. helicopters came under concentrated enemy fire. But despite these developments, few helicopters made it into front-line service during this period.

[85] Ibid., 99-100.

Radar

The Rad Lab was established in 1940 as an independent laboratory staffed by civilian and academic scientists from several disciplines. Funding for the laboratory's first year of operation came from the personal bankroll of financier, philanthropist, and amateur physicist Alfred Lee Loomis, who had also established and operated the highly regarded A. L. Loomis Laboratory in Tuxedo Park, New York [NR, 1980], from 1926-1940.

Although the United States, Germany, and Britain had worked on radar during the mid-1930s, the advent of the war and the need to prevent a coastal attack hastened the development of radar, one of most crucial technical innovations of the war. A British breakthrough in 1940 led to the replacement of bulky ground radars with smaller, more effective radar sets that could be installed in English and American aircraft.[86] In July of 1940 an initial meeting of what ultimately became the National Defense Research Committee's Division 14, or Radar Division, charged a group of assembled scientists with obtaining "the most effective military application of microwaves in minimum time." This resulted in Division 14's development of airborne radar used in the navy for aircraft interception, airborne early warning, and other specialized applications.[87] One of those assembled at the initial meeting, Loomis, a wealthy amateur physicist, had converted his 1901 Tudor Revival house in Tuxedo Park, New York, into a private laboratory in the 1920s where he conducted his own experiments in radar before the war. Loomis met here with the Tizard Mission that brought critical British microwave radar innovations to the United States. He also was instrumental in obtaining government support for radar research and personally funded the first year's work at the Radiation Laboratory at the Massachusetts Institute of Technology (MIT).

Researchers at the Army Signal Corps Laboratory at Fort Monmouth, New Jersey [Camp Evans Historic District, NR, 2002], understood that airplanes in flight could interfere with the transmission and reception of radio signals, and they worked on a gun-laying (the process of aiming an artillery piece) or searchlight-directing radar for antiaircraft artillery.[88] Camp Evans, where the Signal Laboratory was located, functioned as the nerve center of the army's wartime radar research and development. The Signal Laboratory used and coordinated the work of private contractors, such as Bell Labs in New Jersey, Westinghouse in Maryland, and Western Electric in Illinois, along with academic laboratories such as MIT to develop an early warning radar system.

By July 1941, the secretary of the navy had approved the installation of radar aboard carriers. They served as "the brain of the organization," protecting the fleet from air attack. The first installation was on the USS *Hornet*. By August 1941, MIT's Radiation Laboratory scientists were testing radar up to 40 miles, and long-range search radar was being installed in patrol planes and other aircraft. By the end of the war, the navy was using a "winged" radar-guided bomb, known as the "Bat." In one naval engagement, a naval plane launched this device, sinking a Japanese destroyer 20 miles away.[89]

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[86] Bilstein, *Flight in America,* 164.
[87] Deputy Chief of Naval Operations, *United States Naval Aviation, 1910-1980,* 104.
[88] Louis Brown, "Paths for Flight: Innovation and the Development of Radar," in *Innovation and the Development of Flight,* ed. Roger D. Launius (College Station: Texas A&M University Press, 1999), 194.
[89] Ibid., 109; Bilstein, *Flight in America,* 164.

The Army Air Forces also successfully used radio-directed bombs, specifically its own sophisticated AZON (azimuth only) bombs—a standard 1,000-pound bomb to which technicians attached a gyrostabilizing unit and a radio receiver that activated small control surfaces. The bomb resisted spinning and both the rate of descent and the lateral movement could be controlled through radio signals. In the European and Pacific Theaters, the AZON and similar devices proved successful in precision attacks against targets such as bridges.[90]

Ground radar, which the British had used so effectively during the Battle of Britain, became a tool for coastal defense in the United States. Because of the Japanese attack on the American territory of Hawaii and the landings on the Aleutian Islands off the coast of Alaska, the War Department approved a plan to provide the continental coastal frontiers with 31 mobile detectors, beginning with 11 sites along the northeast Atlantic coast and 10 along the Pacific coast. Earlier aircraft warning systems had relied on sound detection devices and ground spotters. With the Signal Corps' development of the mobile radar system known as SCR-270 (with a 120- to 150-mile radius range), the four Army Air Corps interceptor commands "worked feverishly to create a coastal radar net and a supporting corps of ground observers." Thirteen sites were selected along the East Coast and by December 7, 1941, 8 were nearing completion. Ten stations on the West Coast were designed to cover 1,200 miles from the Canadian border to Mexico and, along with 2,300 ground observers, were intended to serve as a first alert for a potential Japanese attack. A rare survivor of this early warning system, Radar Station B-71 [NR, 1998], known as the Trinidad Radar Station or the Klamath River Radar Station, was disguised to look like a clapboard farmhouse and barn from the air.[91]

Conclusion

Wendover Field, located on 1.5 million acres in northwest Utah became the world's largest military base. Wendover's mission was to train heavy bomb groups flying the B-17 or B-24s.[92] For a short time Wendover trained fighter groups on P-47s, one of the most successful American fighter planes of World War II, but this program was abruptly canceled in September 1944 when the Boeing B-29 Superfortress arrived on the field as part of Operation Silver Plate, the highly secretive preparations for the dropping of the first atomic bomb in August 1945. Under intense scrutiny with as many as 400 FBI agents assigned to the airfield, crews learned how to precisely drop one bomb and turn sharply, avoiding the effects of the nuclear blast.[93]

The two nuclear explosions at Hiroshima and Nagasaki in August of 1945 signaled an end to the World War II doctrine of "thousand-plane" bomber raids (in which as many as 4,000 transport aircraft, fighters, bombers, and gliders would be used in a single offensive) and much of the doctrine of strategic warfare that had been devised at the old Air Corps Tactical School. During the conflict, the United States had built nearly 300,000 military aircraft and trained hundreds of thousands of pilots. These aircraft in their wake had left devastation on an unprecedented scale. "By test of war it had become exceedingly clear that neither an Army nor a Navy could either survive or achieve an objective in war without first achieving superiority in the air."[94]

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[90] Bilstein, *Flight in America*, 164.
[91] Gordon Chappell, "Radar Station B-71," National Register of Historic Places Registration Form (Washington, DC: National Park Service, June 7, 1977).
[92] Ibid., 60-61.
[93] McManus, *Deadly Sky*, 14-15. Except for the atom bomb, the B-29 was probably the largest and most complex weapon system of the war, Bilstein, *American Aerospace Industry*, 75; Thole, *Forgotten Fields of America*, 3:153-60.
[94] Grant, *Flight,* 201; Frisbee, *Makers of the United States Air Force*, 7; quote, Deputy Chief of Naval Operations,

Although the war ushered in new methods of mass destruction on an unprecedented scale, the expansion of aviation and the impetus given to key technologies required by the war also laid the foundation for a new age of international air commerce. World War II set a precedent for direct federal aid for airports, brought significant improvements to airports in cities across the nation, advanced radar and air traffic control, and trained aircrew to meet the expansion of civilian air travel. Yet, while international commerce flourished in the post war years, a newly transformed defense industry would face its own challenges during the Cold War.

United States Naval Aviation, 102.

PART FIVE: POST WAR & COLD WAR AVIATION, 1945-1978

C-47s unloading at Templehof Airport in Berlin, as part of the Berlin Airlift between 1948 and 1949. Source: U.S. Air Force Museum, U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Air_Power/berlin_airlift/AP35G8.htm

CHAPTER 13. MILITARY AVIATION & THE COLD WAR, 1945-1975

Somehow in an eyeblink of historical time, American culture transformed from one that abhorred the bombing of civilians to one that not only accepted it as a military norm but viewed it with the kind of enthusiasm formerly reserved for football games.

—H. Bruce Franklin[1]

At the end of World War II, only the United States possessed a nuclear bomb. However, as tensions escalated between the United States and its former ally, the U.S.S.R., the Soviets sought nuclear parity with the United States. In 1949, the Soviets successfully tested their own atom bomb. Five years later the United States responded by testing the even more powerful hydrogen bomb. The arms race that resulted from these tests not only pitted the United States and its democratic allies against the U.S.S.R. and its allies, it also made the threat of nuclear war a very real possibility. Rather than face complete annihilation from nuclear weapons in a "hot war," the United States and the U.S.S.R. engaged in a cold war, in which both countries fought one another indirectly by supporting conflicts in various parts of the world.

Three government policies defined the Cold War era: the "first strike capability" policy of 1945-1953; the "massive retaliation" policy developed in 1954; and the doctrine of "flexible response" of 1961. These policies, along with three major Cold War crises—the Berlin Airlift, the Korean conflict, and the Vietnam War—shaped the structure, operations, and buildup of military aviation during this period. Cold War policies also influenced seminal events in aviation history including the creation of an independent air force, the buildup of the Strategic Air Command (SAC), and the dramatic evolution of the naval aircraft carrier, combat jet aircraft, and the helicopter.[2]

The phenomenal growth of the army's air arm in World War II, and its unique requirements for global responsibilities, led to an independent air force. On July 16, 1947, President Harry Truman approved the National Security Act of 1947, creating both a unified U.S. Department of Defense (initially the National Military Establishment) and an independent air force equal to the army and navy. Officially, the U.S. Air Force became an independent service on September 18, 1947, when Secretary of Defense James V. Forrestal took his oath.

Berlin Airlift

The first challenge facing the independent air force entailed the delivery of food and supplies to West Berlin during the winter of 1948 to 1949, an action at odds with its bomber-oriented doctrine. At the end of World War II, Germany had been divided, with Allied troops occupying West Berlin while Soviet troops occupied East Berlin. Supplies for Allied troops entered West Berlin on overland corridors and through a 20-mile-wide air corridor that the Soviet Union had

[1] H. Bruce Franklin, "'Peace Is Our Profession': The Bombers Take Over," in *The Airplane in American Culture*, ed. Dominick A. Pisano (Ann Arbor: University of Michigan Press, 2003), 333.

[2] The term "Cold War" "was minted by Herbert Bayard Swope, publicist, three-time winner of the Pulitzer Prize, and occasional speechwriter for elder statesman Bernard Baruch. In 1946, about the time [Winston] Churchill was speaking of an Iron Curtain, Swope used 'cold war' in a draft speech for Baruch to describe U.S.-Soviet relations (as contrasted to the recent 'hot' or 'shooting' war)." William Safire, *Safire's New Political Dictionary: The Definitive Guide to the New Language of Politics* (New York: Random House, 1993), 135.

granted to the Western Allies. In the spring of 1948, the Soviets blocked the East German roads leading into the city to halt Allied troop supplies. Because the air corridor remained opened, Allied aircraft, under Gen. Curtis Emerson LeMay, commander of the U.S. Air Force in Europe, ordered supplies flown in for ten days until the Soviets reopened the roads. However, on June 18, the Soviets attempted to take over all of Berlin without a war by blocking all supplies via overland routes into the city. This threatened both the Allies' control of West Berlin along with the well-being of some two million people living in West Berlin.[3]

On April 5, 1948, a Soviet fighter aircraft had "buzzed" a British airliner containing ten passengers. The two crashed head-on. America and Britain responded swiftly, ordering fighter aircraft to escort unarmed transport in the corridor. Rather than risk a shooting war, the Soviets assured western powers of their intent to not interfere with the corridor.[4]

Berlin had only a 36-day food supply and perhaps a 45-day coal stock for 2.5 million people. American officials quickly realized their only option against war or withdrawal was an indefinite airlift carrying life-saving supplies to the West Berliners. President Truman ordered the airlift.[5] On June 1, 1948, air force and navy transport units merged as the Military Air Transport Service to take responsibility for the operation and on June 26, 1948, Douglas C-47s, able to carry 3 tons of cargo, began the airlift. Later the Douglas C-54 Skymaster transport plane, with its larger 10 ton capacity, became the backbone of the airlift.[6]

Gen. William H. Tunner who commanded the airlift, called for an intensive and unrelenting schedule of precision teamwork in July 1948. Fuel and bulk cargo arriving across the Atlantic were unloaded in Germany, shipped to one of two U.S. Air Force airfields, and then sent onto Templehof Airfield in Berlin. Aircraft took off day and night from Templehof in intervals as short as three minutes along a 170-mile path directed by beams from radio ranges and ground radar controller instructions. Once in Berlin a pilot had one chance to land. If he missed his landing due to weather or other reasons, the pilot returned to his home base to reenter the procession. Crews who landed in Berlin stayed onboard and were greeted by a snack wagon and weather updates. After Germans unloaded the cargo, planes returned to their home station where ground crews had 1 hour and 40 minutes to prepare for the next flight.[7]

On May 12, 1949, the Soviets relented and lifted the land blockade. However, airlifts continued until September 30, 1949, delivering reserve supplies in the event the Soviets reinstated the

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[3] R. G. Grant, *Flight: 100 Years of Aviation* (New York: Dorling Kindersley, 2002), 276; Tom D. Crouch, *Wings: A History of Aviation from Kites to the Space Age* (New York: W. W. Norton, 2003), 541; Air Force Historical Studies Office, "The Berlin Airlift," http://www.airforcehistory.hq.af.mil/PopTopics/berlin.htm (accessed August 10, 2005).
[4] Roger G. Miller, *To Save a City: The Berlin Airlift, 1948-1949* (Washington, DC: Air Force History and Museums Program, 1998), 14, 15, http://www.airforcehistory.hq.af.mil/Publications/fulltext/To_Save_a_City.pdf (accessed August 10, 2005).
[5] Charles J. Gross, *American Military Aviation: The Indispensable Arm* (College Station: Texas A&M University Press, 2002), 147. Truman made the decision along with Gen. Lucius D. Clay, the U.S. military governor of Germany, independent of the Joint Chiefs of Staff.
[6] Grant, *Flight*, 277; Air Force Historical Studies Office, "The Berlin Airlift."
[7] General Tunner became known as "Willie the Whip" in his impossible goal of landing an airplane day or night every minute if the ceiling was at least 400 feet at the destination. Air Force Historical Studies Office, "The Berlin Airlift." Pamela Feltus, "The Berlin Airlift," U.S. Centennial of Flight, http://centennialofflight.gov/essay/Air_Power/berlin_airlift/AP35.htm (accessed July 21, 2005). The transports were flown by U.S. Air Force, U.S. Navy, and Royal Air Force crews.

blockade. By then, the transports had made 277,685 flights with 12 crashes that took the lives of 30 servicemen and 1 civilian. It was the most ambitious aerial resupply operation ever undertaken by any nation and served as a model for future humanitarian airlifts. Although the airlift had emerged in response to the threat of war, it now came to be regarded as a symbol of how airpower, rather than armed conflict, could attain national objectives through peaceable means.[8]

FIRST STRIKE CAPABILITY, 1945-1953

The Strategic Air Command

From 1947 through 1960, SAC, the only command that could deliver long-range nuclear weapons, was specifically tasked with maintaining the ability to attack key long-range targets in the Soviet Union. Its bomber force was at the cornerstone of the national strategic policy which sought to deter the Soviet Union's growing nuclear arsenal. Under the policy known as "first strike capability," any sign of aggression by the Soviet Union toward the United States or its allies could trigger the United States into dropping a nuclear bomb on the Soviet Union.[9] This would effectively disable the U.S.S.R.'s military and political force thus eliminating a retaliatory second strike. The creation of both an independent U.S. Air Force and the SAC buildup was central to this first strike capability.

The service inherited three major combat commands from the army: SAC, the Tactical Air Command (TAC), and the Air Defense Command (ADC) formed in March 1946. These commands reflected General of the Army Dwight D. Eisenhower's view of the major functions of airpower: strategic bombardment, air defense, and support of ground forces. Of the three commands, SAC became the most important because "it was responsible for deterrence and, should deterrence fail, for waging atomic warfare."[10] In October 1948, with the Berlin Airlift well under way, Gen. LeMay returned to America and became the SAC commander under its motto of "War is our profession—Peace is our product."[11] Under LeMay, SAC's unprecedented level of striking power came to symbolize America's national strategic policy of deterring the Soviet Union's growing nuclear arsenal.

In 1948, SAC moved its headquarters from Andrews Air Force Base in Maryland to Offutt, a former Air Defense Command base in Nebraska. This move put SAC headquarters closer to other SAC bases while ensuring that SAC remained both outside the range of enemy bombers and missiles and away from Washington, D.C. area air traffic.[12]

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[8] Feltus, "Berlin Airlift"; Air Force Historical Studies Office, "Berlin Airlift."

[9] Pamela Feltus, "Aerospace Power and the Cold War," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Air_Power/cold_war/AP34.htm (accessed July 5, 2005).

[10] Quote, Warren A. Trest and George M. Watson, Jr., "Framing Air Force Missions," in *Winged Shield, Winged Sword: A History of the United States Air Force*, ed. Bernard C. Nalty (Washington, DC: Air Force History and Museums Program, 1997), 1:402; Herman S. Wolk, "The Quest for Independence," in *Winged Shield, Winged Sword*, 1:375-76, 395.

[11] In retrospect, the Naval Aviation Hall of Fame described LeMay "as a symbol of the nation's air power through his combat experience in World War II and his leadership in building up the Strategic Air Command." National Aviation Hall of Fame, "LeMay, Curtis," http://www.nationalaviation.org/website/index.asp?webpageid={F3401AC2-408C-42A7-AD0F-CDDC7942F110}&eID=348 (accessed October 20, 2005).

[12] Frederick J. Shaw, Jr., *Locating Air Force Base Sites: History's Legacy* (Washington, DC: Air Force History and Museums Program, 2004), 57; Global Security, "Strategic Air Command," http://www.globalsecurity.org/wmd/

SAC's Bomber v. the Navy's Supercarrier

On August 29, 1949, the Soviet Union exploded its first atomic bomb. This new threat from the Soviets highlighted the need for long-range bombers, such as the air force's giant B-36 "Peacemaker." The B-36 Peacemaker had entered service in 1948 as the sole aircraft in the world able to transport thermonuclear weapons over intercontinental distances. Although "regarded as a potent deterrent to potential aggressors anywhere in the world," the Peacemaker soon became embroiled in a debate over the navy's demands for a new generation of aircraft carriers.[13]

In July 1948, President Truman authorized construction of the navy's first supercarrier, the USS *United States*. This new generation of carriers would become essential to supporting hundred-thousand-pound aircraft capable of carrying an atomic bomb.[14] However, limited funding forced the navy to compete with the air force. When the air force pushed for the B-36 long-range bomber, construction on the supercarrier was stopped. While air force leaders insisted that the bombing of Hiroshima and Nagasaki proved that a bomber carrying nuclear weapons made other weaponry unnecessary, naval leaders argued that the supercarrier was a better investment as it could launch large bombers carrying nuclear ordnance closer to the target. They also insisted that the B-36 fell short of its billing.[15]

Concerned that the funding of the B-36 would lead to all aviation being placed under one service, the navy and the Marine Corps joined forces to discredit the air force project. Their investigators reported "irregularities" with the aircraft's procurements, although subsequent congressional hearings found no evidence to support this charge. Although the introduction of jet bombers made the piston-powered B-36 obsolete when it entered service in 1948, it remained the only aircraft that could carry thermonuclear weapons between continents.[16]

In March 1949, Truman asked Secretary of Defense Forrestal, a former secretary of the navy and supporter of funds for building the *United States*, to resign in March 1949 over Forrestal's unwillingness to support the president's demands for military spending cuts. Just weeks after taking office, the new secretary, Louis A. Johnson, a supporter of both the air force and Truman's restrictive budget policies, canceled the carrier which was already under construction. These funds were then diverted for additional B-36s needed to support the atomic deterrence force.[17] Funding the B-36s and not the supercarriers meant that the air force would be tasked

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agency/sac.htm (accessed August 24, 2005); Global Security, "Offutt AFB," http://www.globalsecurity.org/wmd/facility/offutt.htm (accessed August 29, 2005).

[13] Quote, Roger E. Bilstein, *Flight in America*: *From the Wrights to the Astronauts* (Baltimore: The Johns Hopkins University Press, 2001), 185; Crouch, *Wings*, 546-47, 550, 557.

[14] Crouch, *Wings*, 549; Gross, *American Military Aviation*, 153.

[15] Pamela Feltus, "Air Power: The Aircraft Carrier," U.S. Centennial of Flight Commission, http://centennialofflight.gov/essay/Air_Power/carriers/AP39.htm (accessed July 5, 2005); U.S. Department of the Navy, "Chronology of Significant Events in Naval Aviation," Naval Historical Center, Part 6, *Postwar Years*, 159, http://www.history.navy.mil/branches/org4-5.htm (accessed June 21, 2005). The Naval Aviation Chronology files contained on this website are excerpts from the Department of the Navy, *United States Naval Aviation 1910-1995*, http://www.history.navy.mil/branches/usna1910.htm.

[16] Feltus, "Aircraft Carrier"; Crouch, *Wings*, 550.

[17] Stephen L. McFarland, "The Air Force in the Cold War; 1945-60: Birth of a New Defense Paradigm," http://www.airpower.maxwell.af.mil/airchronicles/apj/apj96/fall96/mcfarlnd.html (accessed July 29, 2005); Crouch,

with the strategic mission while the navy and army readied for smaller, local wars. Air force leaders believed that its big bombers and atomic bombs would discourage both large and small wars. "According to this logic," states historian Stephen McFarland, "the Navy prepared for local wars it could win but would not need to fight. The Army prepared for a major war it could not win. And the Air Force prepared for a major war it would not fight, while ignoring the local wars it would fight."[18]

The Aircraft Industry & National Defense Planning

In 1947 Secretary of Defense Forrestal described the country's military expenditures as below the minimum required for national security. This level enabled the country to increase funds for Europe's recovery, although at a calculated risk. "As long as we can out-produce the world, can control the sea and can strike inland with the atomic bomb," he wrote, "we can assume certain risks otherwise unacceptable." Forrestal's outlook applied as long as the aircraft industry could meet military mobilization requirements.[19]

But by the spring of 1947, assumptions of a flourishing postwar industry in the wake of a booming civil market failed to materialize. Manufacturers could not survive without government contracts. "The aircraft industry remained from 80 to 90 percent dependent on government purchases of military aircraft," states historian Robert Frank Futrell, and "[t]he Air Force and the Navy had been unable to purchase a quantity of aircraft required to keep industry solvent."[20] In addition, the cancellation of thousands of contracts for aircraft at the end of the war led to unemployment and the industry's difficulties in transitioning to a peacetime environment simply added to these problems.

Fears over whether major aircraft manufacturers could survive as well as the need for a sound aviation policy led President Truman to establish the President's Air Policy Commission. Officially created on July 18, 1947, the commission was commonly known as the Finletter Commission after its chairman, Thomas K. Finletter, a lawyer and wartime special assistant to the Secretary of State. The commission, charged with making recommendations regarding the aircraft industry for the postwar world, submitted its report, *Survival in the Air Age*, on December 30, 1947. The report emphasized support for military air power over concerns for the civilian industry. The air force and navy, the commission forcefully stated, needed to replace its combat aircraft:[21]

> We also must have in being ready for immediate action, a counteroffensive force built around a fleet of bombers, accompanying planes and long-range missiles which will serve notice on any nation which may think of attacking us that it if does, it will see its

Wings, 549.

[18] McFarland, "Air Force."

[19] Robert Frank Futrell, *Ideas, Concepts, Doctrine: Basic Thinking in the United States Air Force, 1907-1960* (Maxwell Air Force Base, AL: Air University Press, 1989), 1:224-25, available at http://aupress.maxwell.af.mil/catalog/books/Futrell_B31.htm (accessed August 16, 2010).

[20] Futrell, *Ideas, Concepts, Doctrine*, 1:225.

[21] Ibid., 225; Donald M. Pattillo, *Pushing the Envelope: The American Aircraft Industry* (Ann Arbor: University of Michigan Press, 2003), commentary 192, 193. "The commission eventually gave attention to five major areas, air power and national security, the aircraft-manufacturing industry, aeronautical research and development, civil aviation, including personal aircraft, and government organization."

> factories and cities destroyed and its war machine crushed. The strength of the counteroffensive force must be such that it will be able to make an aggressor pay a devastating price for attacking us.[22]

"[R]elative security," according to the commission, "is to be found only in a policy of arming the United States so strongly (1) that other nations will hesitate to attack us or our vital national interest because of the violence of the counterattack they would have to face, and (2) that if we are attacked we will be able to smash the assault at the earliest possible moment." The country's security, the commission believed, rested on its airpower.[23]

The Finletter Report emphasized the probability that other countries would develop nuclear weapons and the method to deliver them. Testimony before the commission varied widely as to when this event would occur. With no consensus forthcoming, the commission chose January 1, 1953, as the day the American military air arm should be able to deal with a possible attack. To deter potential aggressors, the report endorsed an increased aircraft inventory for a larger air force.[24] The aircraft industry had just begun to gear up to meet this demand when the Korean War began.

Korean War, 1950-1953[25]

On June 25, 1950, North Korean Communist troops crossed the 38th parallel dividing North and South Korea in a Soviet-backed invasion that drew the United States into a brutal three-year conflict. It was, in the words of Chairman of the Joint Chiefs of Staff Omar Bradley, "the wrong war, in the wrong place, at the wrong time, with the wrong enemy." The air force now faced a ground war for which it was neither trained nor equipped. Since World War II the air force had focused on developing a grand-strategic bomber force that could win a war without ground or sea forces. However, SAC's heavy bombers and nuclear armory were ill-suited for a war in Korea, an agricultural nation which possessed few industrial or military targets.[26] Aircraft carriers, helicopters, and swept-wing fighters were more suited to this type of war.

Although the Korean War revealed limitations in the air force's strategic bomber force, it allowed the navy to recover from the cancellation of the USS *United States*. Because the North Korean navy was small, the U.S. Navy established control of the seas within weeks. American carriers quickly became mobile airfields cruising along the Korean coast, extending U.S. air power into areas with no land bases, and effectively increased the combat time of carrier based jets. According to one source, both the navy and marines "became stalwart performers in the close air support role." In 1951, the carrier's success in Korea convinced Congress to authorize the construction of the *Forrestal* class, a new generation of aircraft carriers.[27]

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[22] "Oral History Interview with Thomas K. Finletter," interview by Jerry N. Hess, January 29, 1972, Harry S. Truman Library & Museum, http://www.trumanlibrary.org/oralhist/finlettr.htm (accessed August 16, 2010).
[23] Futrell, *Ideas, Concepts, Doctrine*, 228.
[24] Ibid., 229.
[25] Portions of "Medevac Helicopters and the Korean War" excerpted from Dwayne A. Day, "M.A.S.H./Medevac Helicopters," http://www.centennialofflight.gov/essay/Rotary/MASH/ HE12.htm, U.S. Centennial of Flight Commission (accessed December 2, 2004).
[26] Quote, Pamela Feltus, "Korean War," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Air_Power/korea/AP38.htm (accessed July 5, 2005); Crouch, *Wings*, 551-52.
[27] Quote, Feltus, "Korean War"; Crouch, *Wings*, 552; Dwight Jon Zimmerman, "Centennial of Naval Aviation,

Along with demonstrating the value of the carrier, the Korean conflict was the first war in which most of the air-to-air fighting involved jets. Over the Yalu River in northwest Korea, high-speed dogfights between the air force's first swept-wing jet fighter, the North American F-86 Sabres, and the Russian MiG-15s in "MiG Alley" kept enemy aircraft away from American air operations farther south. Both the Russian and American aircraft featured the swept-wing design, an important aerodynamic innovation that "delayed the buildup of draft as aircraft approached the speed of sound."[28] On offensive sweeps, Sabres flew 10 miles in less than 30 seconds, attaining a "legendary status as a classic of aerial combat even while it happened."[29]

Along with aircraft carriers and jet aircraft, the Korean conflict underscored the importance of the helicopter. Following their introduction into military service at the end of World War II, helicopters had increased in popularity. In Korea, helicopters became "firmly entrenched in the inventories of the army, the navy, the marines, and the air force."[30] The omnipresent helicopter conducted artillery spotting, airlifting, and supply missions. It helped mine-sweeping ships navigate and provided commanders with "a more intimate knowledge of conditions."[31]

Medical evaluations were probably the helicopters most valued mission. The Bell 47 and the Sikorsky S-51 were the primary rescue helicopters used in the Korean War. First flown in 1946, the Sikorsky S-51 helicopters (designated the H-5 by the military), were often called upon to rescue downed pilots, sometimes behind enemy lines. They also were pressed into service as aerial ambulances. U.S. Air Force Air Rescue Service units flew H-5s, and later joined Marines in flying wounded soldiers between frontline aid stations, field hospitals, and a navy hospital ship. These flights saved precious time in providing lifesaving medical care. In February 1952, the larger H-19s, capable of carrying nine litters and having a flight radius of 120 miles, began replacing the H-5s which could only carry one litter and fly 85 miles.[32]

The Bell 47 was the first commercially certified helicopter (in March 1946). It was used extensively during the Korean War when it shifted from a light utility and observation role to a flying ambulance. Nicknamed the "Sioux," the Bell-47 (designated the H-13 by the military) could normally carry a pilot and two passengers in its bubble-enclosed cockpit. Stretchers located outside the cockpit and atop the landing skids enabled a pilot to ferry wounded troops from the front lines to the Mobile Army Surgical Hospitals (M.A.S.H.).[33] The helicopter's two-bladed rotor made a "chop-chop" sound, leading to the nickname "chopper" for helicopters.

Carriers at War," The Year in Defense, Defense Media Network, http://theyearindefense.com/about/defense-media-network (accessed August 18, 2010).

[28] Quote, Trest and Watson, "Framing Air Force Missions," 410; Pattillo, *Pushing the Envelope*, 171. The area in southwest Korea nicknamed "MiG Alley" was a 6,500-square-mile area bordered by the Yellow Sea, Yalu River, and China. Feltus, "Korean War."

[29] Feltus, "Korean War"; quote, Grant, *Flight,* 279.

[30] Bilstein, *Flight in America*, 189.

[31] Otto Kreisher, "The Rise of the Helicopter During the Korean War, HistoryNet, http://www.historynet.com/the-rise-of-the-helicopter-during-the-korean-war.htm/ (accessed August 18, 2010) originally published in *Aviation History*, January 2007.

[32] National Museum of the US Air Force, "Sikorsky YH-5A Dragonfly," http://www.nationalmuseum.af.mil/factsheets/factsheet.asp?id=280 (accessed August 17, 2010); Kreisher, "Rise of the Helicopter."

[33] The Bell 47 was featured at the beginning of the television show *M.A.S.H.* bringing wounded soldiers to the field hospital. This aircraft proved to be one of the most successful helicopters of all time, staying in production for over three decades.

Many soldiers owed their well being and their lives to medevac helicopters. Over twelve months in 1951, army helicopters carried 5,040 wounded and, in mid-1953, that number increased to 1,273 wounded carried in just one month. "Costly, experimental and cranky," one army historian concluded, "the helicopter could be justified only on the grounds that those it carried, almost to a man, would have died without it." Later in the conflict, more advanced helicopters conducted tactical movements, a harbinger of the war to come.[34]

MASSIVE RETALIATION, 1954-1961

Eisenhower, who had retired from active military duty in 1952 and won the 1952 presidential election, entered office in 1953 determined to develop both a balanced federal budget and a strong military force. To balance the budget, President Eisenhower intended to reduce Pentagon spending but still maintain modern weapons to dissuade the expansion of global Soviet power. Rather than a balanced military force (with ground forces), he envisioned a military force equipped with "nuclear-armed, long-range aircraft and missiles supported by strong naval forces." Eisenhower's "New Look" program, and its emphasis on "massive retaliation," would devastate the Soviet Union at any sign of aggression. Seen as the best solution to the nation's security problems, the program vindicated those who had advocated for the dominance of air power during the 1930s.[35] Despite the practical lessons of the Korean War, the air force remained focused on the strategic nuclear mission under the massive retaliation policy. A new generation of bombers, fighters, and aircraft carriers, advanced by a growth in research facilities, emerged as a result of this policy.

Between 1955 and 1956, a new intercontinental bomber began replacing the B-36 "Peacemaker." Boeing's swept-wing B-52, which had been envisioned as early as October 1948, "set new standards for strategic bombers." Described by Tom Crouch as "the most successful design in the history of military aviation," the B-52 became the standard bomber for the air force and the mainstay of SAC's bomber force for the rest of the Cold War.[36]

The new generation of fighter aircraft was based on the swept-wing configuration of the MiGs and Sabres that had fought over the Yalu River in Korea. Designers for the navy produced the Chance Vought F-8 Crusader and the McDonnell F-4 Phantom. In 1955 the Crusader became the first carrier plane to fly over 1,000 mph and make carrier takeoffs and landings.[37] During the 1960s through the 1970s, McDonnell's Phantom F-4 became a phenomenally successful design, and was subsequently adopted by the U.S. Air Force, the Royal Air Force, and several other air forces. First put into service in 1960, the F-4 was capable of speeds exceeding Mach 2, twice as fast as the speed of sound. The plane carried a "weapons officer" to operate its advanced electronic equipment, including sophisticated radar to detect hostile aircraft and monitor the readiness of its own missile defense and attack systems. The McDonnell F-4 represented both the growing capabilities as well as the growing electronic complexity of postwar combat aircraft.

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[34] Kreisher, "Rise of the Helicopter."
[35] Gross, *American Military Aviation*, 176.
[36] Crouch, *Wings*, 558-60, 559 for commentary; quote, 560; David Miller, *The Cold War: A Military History* (New York: St. Martin's Press, 1998), 125. Crews nicknamed the plane "BUFF," for the Big Ugly Fat Fellow.
[37] Bilstein, *Flight in America*, 219.

Produced for 21 years, "[i]ts success would make McDonnell the strongest military firm in the industry."[38]

The navy's new generation of aircraft called for its first supercarriers designed and built for jet aircraft operations. The *Forrestal* featured three important British innovations: an angled flight deck, a powerful steam catapult, and a new landing system. The angled deck allowed an aircraft that missed the arresting wires on landing to take off again rather than run into parked aircraft. The new landing system and the steam catapult, that replaced a hydraulic catapult, were essential for the navy's new heavier aircraft.[39] Together, the navy viewed these new features as "representing the most significant advance in aircraft carrier operating capability since World War II."[40] After the *Forrestal* was launched in December 1955, the carriers *Saratoga, Independence,* and *Ranger* followed at approximately one-year intervals. Four additional supercarriers designated by the *Kitty Hawk* class were all commissioned in the 1960s along with the navy's first nuclear-powered carrier, the *Enterprise*, commissioned in 1961.[41]

Like the navy, the air force obtained new military aircraft whose design had benefited from the lessons learned in the Korean skies. The so-called Century series, produced by various manufacturers, was "intended to maintain air superiority against opposing fighters and to blunt the awesome threat of Russia's rapidly growing long-range strategic bomber fleet." The first Century aircraft, the F-100 Super Sabre designed by North American, was the first U.S. production fighter intended for supersonic flight over sustained periods. It began service with the air force in 1954.[42]

During the Cold War era, a number of World War II–era installations continued to play a key role in America's national security. In addition to Wright-Patterson, Muroc (renamed Edwards Air Force Base), the Arnold Engineering Development Center, Arnold Air Force Base, in Tullahoma, Tennessee, became an early postwar military facility with a complex of specialized wind tunnels and related facilities for the study of high-speed flight and technologies required for the evolution of advanced military aircraft. NACA also experienced a growth in research facilities that could be used to develop new aeronautical technology for both military and civil applications, this led to postwar construction at Langley, Lewis (now Glenn) in Cleveland, and Ames near San Francisco.

In addition to aeronautical technology facilities, the air force, with the assistance of Department of Defense planners, established Project RAND (so named from a contraction of the term "R and D," standing for research and development) as a think tank to consider national security options and the range of technologies that might be needed for implementation in the future. Originally assigned as a contract to Douglas Aircraft and housed within the company's administrative offices, RAND soon morphed into a separate, nonprofit corporation with headquarters in downtown Santa Monica. RAND reports, both classified and unclassified, continued to influence a broad range of defense policies.[43]

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[38] Pattillo, *Pushing the Envelope*, 185, 204.
[39] Crouch, *Wings*, 556.
[40] Department of the Navy, "Chronology of Significant Events in Naval Aviation," 183.
[41] Bilstein, *Flight in America*, 220.
[42] Ibid., 220-21.
[43] Alfred Goldberg, ed., *A History of the United States Air Force* (New York: Arno Press, 1974), 99-114, 197-214; Roger E. Bilstein, *Testing Aircraft, Exploring Space: An Illustrated History of NACA and NASA* (Baltimore: Johns

"The decade of the 1950s," according to one author, "probably was, in aeronautical development, the most exciting and fruitful in the history of American aviation and represented the apogee of the aircraft industry. The number and variety of new models developed and the pace of progress was equaled in no other decade. By 1960 the transition to jet combat aircraft was almost complete, and fighters of not only supersonic but of Mach 2 capability were increasingly commonplace."[44]

FLEXIBLE RESPONSE, 1961

President John F. Kennedy's new administration in 1961 changed military strategy. Unlike Eisenhower, Kennedy and his advisers believed that increased defense spending and tax cuts, rather than controlling military spending, would stimulate the economy. Kennedy "became a believer in matching response to provocation."[45] His strategy of "flexible response" required a balanced military force that would allow the United States to be highly selective of the weaponry and intensity of the nation's response to varying circumstance and situations. Flexible response "became the cornerstone of defense policy in the sixties" and Secretary of Defense Robert McNamara its "primary architect and director."[46] This strategy shaped the confrontations in Cuba and Vietnam.

Looking Glass

Both McNamara's commitment to flexible response and his belief that the intercontinental ballistic missile (ICBM) being developed would be a greater deterrent than the long-range strategic bomber, led to the creation of an airborne command. In February 1961, SAC headquarters at Offutt began operating a round-the-clock fleet of three specially equipped KC-135 tankers. One aircraft remained airborne eight hours until relived by another. Looking Glass, nicknamed for its ability to mirror the capability of SAC's underground command center, served as an airborne command post in the event the underground facility at Offutt Air Force Base should be destroyed. Concerns over the safety of other command posts placed auxiliary airborne command posts at Barksdale Air Force Base in Louisiana, Westover Air Force Base in Massachusetts, and March Air Force Base in California.[47] These aircraft remained airborne continuously for three decades. From 1961 to 1990, a full crew could provide retaliatory response at any time if ordered. Looking Glass aircraft were retired in 1998, after logging more

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Hopkins University Press, 2003), 37-50, 58-62; Roger E. Bilstein, *The Enterprise of Flight: The American Aviation and Aerospace Industry* (Washington, DC: Smithsonian Institution Press, 2001), 79. For information on the electronics revolution, see Albert Helfric, *Electronics in the Evolution of Flight* (College Station: Texas A&M Press, 2004).

[44] Pattillo, *Pushing the Envelope*, 199.

[45] Drue L. DeBerry, R. Cargill Hall, and Bernard C. Nalty, "Flexible Response: Evolution or Revolution?" in *Winged Shield, Winged Sword*, 2:169. The flexible response solution "reflected the thinking of General [Maxwell] Taylor, the Army Chief of Staff from 1955-1959."

[46] Lieutenant Colonel Laurel A. Mayer and Dr. Ronald J. Stupak, "The Evolution of Flexible Response in the Post-Vietnam Era," *Air University Review*, Nov.-Dec. 1975, http://www.airpower.maxwell.af.mil/aureview/1975/nov-dec/mayer.html (accessed August 19, 2010).

[47] Walter S. Moody, Jacob Neufeld, and Bernard C. Nalty, "The Air Force and Operations Short of War," in *Winged Shield, Winged Sword*, 2:212-13.

than 280,000 hours of accident-free flying time. Its mission was transferred to the navy's E-6B TACAMO (Take Charge and Move Out) aircraft.[48]

Skunk Works and Spy Planes

To remain up-to-date on potential targets and to keep informed of any possible aggressive intentions, the air force relied on a new type of plane for aerial reconnaissance. "A curious press," states one historian, "quickly tagged the aircraft 'spy planes'."[49] Under a shroud of secrecy, an elite, small design group led by legendary and innovative designer Clarence "Kelly" Johnson at Lockheed Aircraft Company in Sunnyvale, California, produced pacesetting airplanes such as the very high-altitude subsonic U-2 reconnaissance airplane in the 1950s, and the very high-speed supersonic SR-71 Blackbird reconnaissance plane in the 1960s. Working from "a temporary building constructed of packing crates and a rented circus tent" the design group developed "one remarkable plane after another."[50] Located next to an odor-producing plastic-manufacturing plant, the facility was nicknamed "Skunk Works," in honor of the forest hideaway ("Skonk Works") where the characters in Al Capp's *L'il Abner* newspaper comic strip brewed their "kickapoo joy juice" out of old shoes, skunks, and other ingredients.[51]

SR-71 production at Lockheed Skunk Works, 1965. Source: https://www.cia.gov/library/center-for-the-study-of-intelligence/csi-publications/books-and-monographs/a-12/images-and-thumbnails/ch2_1.jpg

The U-2, the American Central Intelligence Agency's (CIA) first spy plane, is associated with the 1962 Cuban missile crisis that nearly escalated to nuclear war. On October 14, U-2 spy planes photographed the Soviet Union's attempt to install bases on Cuba for ballistic missiles aimed at the United States. Fourteen tense days followed in which the Cold War enemies faced

[48] nebraskastudies.org, "Looking Glass," http://www.nebraskastudies.org/0900/stories/0901_0124.html (accessed August 27, 2005); "Cold War Leftovers—Davis Monthan and AMARC," http://www.duotone.com/coldwar/aircraft/ (accessed August 27, 2005).
[49] Bilstein, *Flight in America*, 225.
[50] Grant, *Flight*, 264; Crouch, *Wings*, 284; quote, 494. In June 1943, Kelly Johnson and his team of 123 engineers and technicians designed their first product, the XP-80 Shooting Star that first flew in 1944 and was "the first U.S. operational jet fighter, the first U.S. airplane to fly 500 miles per hour, and the first U.S. jet to see combat." Crouch, *Wings*, 494.
[51] Lockheed Martin, "How the Skunk Works® Got Its Name," http://www.lockheedmartin.com/wms/findPage.do?dsp=fec&ci=16507&rsbci=16504&fti=0&fti=0&sc=400 (accessed August 27, 2005). "The Skunk Works model served as a pattern for similar operations in the aerospace industry. In the 1980s, when NASA's Johnson Space Center began serious designs for its space station, it sequestered its own Skunk Works crew in an off-site office complex while they hammered out a baseline design." Bilstein, *Enterprise of Flight*, 98.

the fearful vision of nuclear war. Finally, "the Soviets blinked" as Secretary of State Dean Rusk famously put it. They removed the missiles. Khrushchev noted that the nuclear threat, especially the fact that "20 percent of all Strategic Air Command planes, carrying atomic and hydrogen bombs, were kept aloft around the clock," had been very influential in the withdrawal decision.[52]

Lockheed's SR-71 Blackbird, also developed for the CIA, became the country's leading strategic reconnaissance aircraft. The aircraft was both the fastest in the world when it premiered on December 22, 1964, and when it retired in 1990. Its speed "provided the means for impressive flexibility and rapid action in response to fast-breaking events."[53] Overall, "[t]he Blackbird's performance and operational achievements placed it at the pinnacle of aviation technology developments during the Cold War."[54]

Vietnam, 1961-1973

In 1959, North Vietnamese Communist leader Ho Chi Minh started a civil war in South Vietnam, vowing to spread communism throughout Vietnam. Upon its entry into the Vietnam War in 1961, America possessed the world's most powerful air force. However, the country faced a new type of war. According to retired air force colonel and historian John Schlight, "[t]he United States Air Force was not fully equipped, suitably trained, nor doctrinally prepared for the situation in Southeast Asia. The transition from massive retaliation to flexible response and the shift from nuclear to conventional weapons remained incomplete."[55] Because political factors limited the use of airpower, both the air force and navy faced a long and unpopular counterinsurgency effort against an elusive enemy. The war which ensued "cut short a presidency that had brought social justice to millions, sent hundreds of thousands of people into the street in protest, and inaugurated an era during which millions of Americans would lose faith in their government."[56]

Rolling Thunder, 1965

The United States became fully embroiled in the Vietnam war after Communist patrol boats twice allegedly attacked the USS *Maddox*, a navy destroyer on patrol in the Tonkin Gulf on August 2 and 4, 1964. On August 7, Congress passed the Tonkin Gulf Resolution giving President Lyndon B. Johnson authority to take necessary measures "to repel any armed attacks against the armed forces of the United States and to prevent further aggression."[57] A few months later, in March 1965, America waged the war's first systematic bombing campaign, Operation

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[52] Feltus, "Aerospace Power."
[53] Bilstein, *Flight in America*, 301. In 1976, the SR-71 "set a world speed record at 2,193.167 miles per hour, but its true top speed remains classified information." The SR-71 was reactivated in 1995. Feltus, "Aerospace Power."
[54] Smithsonian National Air and Space Museum, "Lockheed SR-71A Blackbird," http://www.nasm.si.edu/collections/artifact.cfm?id=A19920072000 (accessed October 18, 2010).
[55] John Schlight, "The War in Southeast Asia, 1961-1968," in *Winged Shield, Winged Sword*, 2:260.
[56] Crouch, *Wings*, 571.
[57] Gross, *American Military Aviation*, 196, commentary 207. The military engaged in another major air bombing campaign. Begun in December 1964, the Laotian air campaign, aimed at transportation and antiaircraft artillery, is associated with the Ho Chi Minh trail developed by the North Vietnamese to move troops and supplies. An air campaign in northern Laos, to protect radar sites there, began in June 1964.

Rolling Thunder, against North Vietnamese military, industrial, and transportation targets. It was hoped that this bombing campaign would bring North Vietnam to the negotiating table.

Precision bombing in Rolling Thunder called for both air force and naval fighter bombers. Republic's F-105 Thunderchief, a supersonic tactical fighter-bomber developed for the air force, "established an excellent record in Vietnam."[58] The Chance Vought F-8 Crusader and the McDonnell F-4 Phantom II, supersonic aircraft developed for the navy in the aftermath of Korea, became "two of the finest multi-role supersonic fighters of the Vietnam era."[59]

Bombing halts during Rolling Thunder allowed the North Vietnamese time to "repair damaged facilities and build the world's most formidable air defense system." That system included a massive surface-to-air missile (SAM) arsenal. A new urgency in electronic warfare emerged as the air force responded with its F-100 Super Sabres and F-4Gs "modified to identify, locate and physically suppress or destroy ground-based enemy air defense systems." Code-named "Wild Weasels," these aircraft fired "missiles that home in on the defense system's electromagnetic energy emitted" from the radar system tracking the aircraft.[60] Once the installations were detected by the plane's missile site radar, weapons known as Shrikes were fired. The Shrikes homed in on the radar emission and destroyed SAM sites.[61]

Top Gun Pilot Training, 1969

After Rolling Thunder ended in 1968, the navy concluded that improvements to its air combat training program were needed. Two MiGs had been downed for every U.S. fighter lost, a lower air kill ratio than that of the Korean war. In March 1969, the Naval Air Systems Command established its Post-Graduate Course in Fighter Weapons, Tactics, and Doctrine at Miramar Naval Air Base in San Diego. Nicknamed "Top Gun," this program was later made famous by the movie of the same name. This training proved itself in April 1972, when President Nixon resumed the bombing campaign in North Vietnam known as Linebacker. MiGs chose to focus on air force fighters rather than engage navy aircraft. "North Vietnamese and air force fighters fought on more of less even terms until the end of Linebacker II," states historian Charles Gross, "while navy aircrews ran up a 12:1 kill advantage."[62]

In the wake of the navy's program, the air force started its own program called "Red Flag" in 1975 at Nellis Air Force Base near Las Vegas, Nevada. There, pilots not only received instruction in theory and practice, they also experienced realistic air-combat maneuvers when pitted against instructors who flew lighter-weight aircraft similar to enemy fighter planes. Pilots completing these programs were especially well-trained.[63]

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[58] Pattillo, *Pushing the Envelope,* 236. This was the first fighter aircraft designed with an internal bomber bay.
[59] Bilstein, *Flight in America,* 219-20.
[60] Boeing, "Wild Weasel," http://www.boeing.com/defense-space/military/f4/wildweasel.htm (accessed October 18, 2010).
[61] Crouch, *Wings,* 572; Pamela Feltus, "Air War in Vietnam," U.S. Centennial of Flight Commission, http://www.centenialofflight.gov/ essay/Air_Power/Vietnam/AP40.htm (accessed July 5, 2005); Grant, *Flight,* 306.
[62] Gross, *American Military Aviation,* 213. Gross points out other factors accounting for the navy's higher kill ratio over that of the air forces. Such factors included differenced in radar coverage, aging v. capable MiGs, and areas of operation.
[63] Grant, *Flight,* 306. Some of the *Top Gun* movie footage was shot at Miramar, http://www.miramar.usmc.mil/ miramar/history.htm (accessed October 7, 2005, site since removed); Crouch, *Wings,* 575.

The First Helicopter War[64]

Beyond Rolling Thunder, America conducted another air campaign during the war within South Vietnam in which "the ubiquitous helicopter emerged as the universal image of the conflict in the American popular mind."[65] Following its success in developing and testing armed helicopters, the army convened a high-level board on January 15, 1960, to assess the possibility of using more fixed-wing aircraft and helicopters. The Army Aircraft Requirements Review Board, also known as the Rogers Board after its chair, Lt. Gen. Gordon B. Rogers, had as its primary mission the upgrading of army aviation. The board recommended the UH-1 Huey helicopter and the CH-47 Chinook cargo helicopter for use in Vietnam.[66] By the middle of the war, the helicopter had become as important to the army as the tank, the armored personnel carrier, and the jeep, with the Huey as the most iconic weapon of the Vietnam War.[67]

In 1961, President Kennedy's military advisor, Gen. Maxwell Taylor, authored a report emphasizing how Vietnam's poor road system and difficult geography limited mobility by the Army of the Republic of Vietnam (ARVN). Kennedy ordered the 8th and 57th Transportation Companies (Light Helicopter) which were deployed to Vietnam in early 1961 to use the Piasecki H-21 Shawnee as their helicopter of choice. This marked the "first major commitment of combat power by the U.S. to Vietnam and the beginning of a new era in military history—airmobility."[68]

In the spring of 1962, McNamara instructed Gen. Hamilton H. Howze, the army's first Director of Aviation, to chair a board to study the tactical mobility of ground forces, especially the use of helicopters to transport troops to a given area. The Howze Board convened at Fort Bragg in North Carolina. Following tests and studies, the board theorized that army aircraft, particularly helicopters, would "enhance the combat effectiveness of ground forces." However, the Department of Defense did not immediately act on this recommendation; instead they created an air assault division to test aspects of airmobility.[69] Between 1963 and 1965, air assault tests were carried out stateside by the 11th Air Assault Division established at Fort Benning, Georgia. This division also visited units stationed in Vietnam "for cross-fertilization of ideas."[70] These test units were responsible for forming, training, and equipping six airmobile companies that were mobilized to Vietnam during the trial period. The tests were ultimately deemed a success.[71]

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[64] Portions of "Vietnam: The First Helicopter War" excerpted from Day, "Search and Rescue Helicopters," http://www.centennialofflight.gov/essay/Rotary/SAR/HE9.htm, and "Helicopters at War," http://centennialofflight.gov/essay/Rotary/Heli_at_War/HE14.htm (accessed December 2, 2004).

[65] Gross, *American Military Aviation*, 199.

[66] Army Aviation Museum, "The Role of the Helicopter in the Vietnam War," http://www.armyavnmuseum.org/history/war/rvn/rvnhelo2.html (accessed Aug. 24, 2010). In 1955, army aviators at Fort Rucker, Alabama, began developing armed helicopters. Gross, *American Military Aviation*, 200.

[67] Gross, *American Military Aviation*, 200-01; Jim Mesko, *Airmobile: The Helicopter War in Vietnam* (Carrolton, TX: Squadron/Signal Publications, 1984), 4-5.

[68] Mesko, *Airmobile*, 5 for quote, 17; John Everett-Heath, *Helicopters in Combat: The First Fifty Years* (New York: Sterling Publishing Company, 1993), 68.

[69] Army Aviation Museum, "The Role of the Helicopter."

[70] Lt. Gen. John J. Tolson, *Vietnam Studies: Airmobility 1961-1971* (Washington, DC: U.S. Department of the Army, 1989), 51, 54, http://www.army.mil/cmh-pg/books/Vietnam/Airmobility/airmobility-fm.html/ (accessed August 31, 2005).

[71] Mesko, *Airmobile*, 5; Tolson, *Vietnam Studies*, 51, 54; Everett-Heath, *Helicopters in Combat*, 77 and commentary. One of the culminating activities of the test period was a massive exercise conducted in a four million acre area in the Carolinas involving 35,000 men named Air Assault II. For a detailed discussion of the Air Assault

As the war escalated, the army quickly refined the use of the helicopter. In 1965, Secretary of Defense McNamara approved greater airmobility for ground forces. On July 1, the 11th Air Assault Division, renamed the 1st Cavalry Division (Airmobile) was sent to Southeast Asia to join the Vietnam conflict. Equipped with guns, grenade launchers, rockets, or even guided missiles, the helicopter provided rapid and wide-ranging fire against an adversary on the ground. With a helicopter, an American commander could "bring in additional troops quickly to aid an engaged unit while at the same time deploying other units to trap the communist troops."[72] By November 1965 the helicopter had demonstrated the benefits of air mobility, ushering in a radically different way of fighting a war.[73] Instead of armies engaging each other across vast fronts, advancing slowly, and then holding ground, the army could now quickly carry troops into hostile territory and remove them after the fighting ended. While the overall strategy was questionable—no territory was ever really held—the tactic was often very successful in the short term.

By enabling rapid troop movements, helicopters could provide a tremendous element of surprise. An enemy who had been unchallenged for days or weeks could suddenly, without warning, find itself under assault from troops brought in by helicopter. Equally importantly, "[i]n the dense jungles, helicopters eliminated long, vulnerable supply routes to remote outposts.… [R]apid evacuation of wounded personnel kept down combat deaths and became a strong morale factor."[74] Large troop transport helicopters like Piasecki's CH-47 Chinook were developed for moving troops into and out of battle, but the workhorse UH-1 Huey became the most popular helicopter for troop movements.

In early 1962, when the 57th Medical Detachment (Helicopter Ambulance) went to Vietnam to provide medevac service to the ARVN forces, the UH-1A Hueys quickly became the primary medevac helicopter used. They were nicknamed "Dustoff" for the dirt they kicked up as they took the wounded to safety. Although rarely armed, Dustoff Hueys sometimes dropped off supplies and even ammunition to troops in the field—what one pilot referred to as "preventive medicine." They frequently came under fire and many were shot down (the large red crosses painted on their sides did not provide immunity).[75]

In late 1963, the U.S. Air Force took delivery of the first Sikorsky HH-3E helicopter, also known as the Jolly Green Giant. It became the primary search-and-rescue helicopter for the air force during the war. Bigger fuel tanks enabled it to travel deep into North Vietnam to retrieve downed airmen. By the latter part of 1964, the army had 260 helicopters in South Vietnam. A large majority of these were Hueys, with a smaller portion of the OH-13 Sioux and OH-23 Ravens, along with a few Mojaves. The Marine Corps also had a small squadron of 24 UH-34s to support ARVN divisions.[76]

Tests, see Tolson, *Vietnam Studies*.

[72] Army Aviation Museum, "The Role of the Helicopter"; Mesko, *Airmobile*, 20.

[73] Gross, *American Military Aviation*, 201.

[74] Ibid.

[75] By the 1980s, the U.S. Army began replacing the Huey with the Sikorsky UH-60 Black Hawk in the medevac role. The military's requirement was the ability to carry a greater number of wounded. Day, "Helicopters at War."

[76] Everett-Heath, *Helicopters in Combat*, 75.

Training of Vietnam-Era Army Helicopter Pilots

Training of army helicopter pilots first took place at Fort Rucker, Alabama, at the Army Aviation School, but during the height of the Vietnam conflict in 1966, the secretary of defense called for training a large number of army helicopter pilots. Fort Rucker, which was already operating at full capacity, could not accommodate additional students. On April 1, 1967, Hunter Air Force Base was transferred to the army for this type of training and renamed Hunter Army Airfield. The base operated in conjunction with Fort Stewart (Hunter Army Airfield, U.S. Army Flight Training Center, Savannah, Georgia) located 40 miles southwest. On July 28, 1967, the facilities at Fort Stewart and Hunter Army Airfield were officially renamed the U.S. Army Flight Training Center, and advanced instruction in helicopter training for Republic of Vietnam Air Force students began on March 13, 1970.[77]

Helicopter training also took place at the U.S. Primary Helicopter Center and School located in Fort Wolters, Texas. During the Vietnam War, the school expanded to three heliports (Main, Downing, and Dempsey) and 25 stage fields. The first seven of these stage fields had western names while the rest were named after actual towns in Vietnam. This ensured students' familiarity with place names in Vietnam. To familiarize students with Vietnamese geography, the fields were also positioned directionally to mimic the positioning of Vietnamese towns. Over its 17 years of operations, 41,000 students graduated from the U.S. Army Primary Helicopter Center and School at Fort Wolters. Students from over 30 countries were among its graduates. Its peak output occurred in 1967 when 600 students graduated each month. The school closed its doors in November 1973.[78]

Airmobility came at a heavy price. During the Vietnam War, the United States lost 4,869 helicopters (with more than 1,000 lost in 1968 and another 1,000 in 1969). Fifty-three percent of these losses were due to enemy fire (including enemy attacks on airbases). The rest resulted from operational accidents. The high rate of operational accidents occurred largely because helicopters are prone to mechanical breakdown if not regularly maintained. During war, maintenance suffered. Vietnam's heavy jungle canopy also made helicopter operations difficult as stricken helicopters had few places to land.

Although the helicopter was first used during World War II, it did not become an integral part of an American conflict until the war in Vietnam. Drawing on the technological advantages made during and after World War II, the helicopter proved its worth during the Vietnam War. In fact, Richard Stewart has argued that "[b]esides the Special Forces, the Army's most important contribution to the fight was the helicopter."[79]

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[77] U.S. Army Installation Management Agency Southeast Region, "Hunter Army Airfield History," Fort Stewart/Hunter Army Airfield, http://www.stewart.army.mil/ima/sites/about/history-haaf.asp (accessed September 6, 2005). The headquarters of the U.S. Army Aviation School Element was later known as the U.S. Army Flight Training Center.

[78] Jerry Barnes and Ira Will McComic, "The U.S. Army Primary Helicopter Center and School," Fort Wolters Tour, http://www.fwcvhpa.org/fw/fw.htm (accessed September 26, 2004).

[79] Richard W. Stewart, ed., *American Military History* (Washington, DC: U.S. Army Center of Military History, 2004), 630, http://www.army.mil/cmh-pg/books/AMH/AMH-28.htm/ (accessed May 24, 2005).

War's End

After Johnson ended Rolling Thunder bombing operations in early November 1968, North Vietnam agreed to join peace talks. Bombing then ceased until the spring of 1972 when a North Vietnamese offensive began. In response to this offensive, President Richard Nixon suspended the peace talks and ordered the Linebacker raids with the primary objective of slowing the enemy's advance. Peace negotiations began again in October only to end in December after North Vietnam left the negotiations. Again Nixon ordered a bombing campaign using B-52s to bomb Hanoi and Haiphong from December 18 to 29. "Not until the Linebacker Operations of 1972," writes one resource on military matters, "was airpower brought fully to bear against North Vietnamese forces and facilities." Peace talks resumed in January and a cease-fire was finally signed on January 23, 1973.[80]

North Vietnam invaded South Vietnam again in 1975 and took over the country in two months without any U.S. intervention. On April 29, as Communists approached Saigon, 70 Marine Corps helicopters transported 1,000 Americans and 7,000 Vietnamese from that city to aircraft carriers, resulting in the largest helicopter evacuation in history and an end to the tragically long war.[81]

[80] Feltus, "Air War in Vietnam"; quote, Global Security, "Strategic Air Command."
[81] Feltus, "Air War in Vietnam."

CHAPTER 14. CIVIL AVIATION, 1946-1958

COMMERCIAL AVIATION

[A] horde of civilian passengers descended on the airlines. It seemed as if those who had been denied the chance to travel by air suddenly flocked to fly—and the airlines were not ready for them.

–Carl Solberg[1]

The Golden Era of the Postwar Propliners

The end of World War II marked the emergence of major advances in global aviation and a "transformation in the scale" of the industry. The number of aircraft had climbed by nearly 40 percent during the war and aviation technology had kept pace with the improved planes and infrastructure. Airline personnel now had experience in traveling worldwide and civilians who had faced wartime travel restrictions were ready to fly again.[2] Under War Department rules, non-priority passengers had, in essence, been grounded during the war as free seats were primarily available on inconvenient flights with multiple stops or out-of-the-way routes. These conditions prompted the now familiar terminology of "standby" and "bumped." Civilian travel had also been hampered by a lack of civil aircraft. The military had taken over 200 planes, leaving only 165 planes for civilian travel.[3]

With peace and an end to wartime travel restrictions, airline companies simply had to "wheel the planes up to the gates and stand back for the flood of people crowding to travel the fast, modern way." American and United bought war-surplus C-54s and retrofitted them with seats, toilets, and galleys for passengers, but converting military planes for passenger travel took time. Passengers who wanted to book flights often learned that the next available flight was three weeks away. Terminals were "a madhouse of people seeking information, clerks who didn't know the answers, lost passengers looking for their luggage, and families meeting arrivals." In 1946, Chicago's Midway Airport recorded 1.3 million passengers alone, a number 20 times greater than prewar figures.[4]

In the postwar period, airlines competed for both transcontinental and transoceanic routes. They demanded advanced airliners that flew farther, carried more passengers, and set new standards in performance and comfort, and the aviation industry complied with their demands. Propliners with romanticized names, such as Lockheed's Super Constellation and Boeing's Stratocruiser now transformed the American flying experience.

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[1] Carl Solberg, *Conquest of the Skies: A History of Commercial Aviation in America* (Boston: Little, Brown, 1979), 333.

[2] Ibid., 323; R. G. Grant, *Flight: 100 Years of Aviation* (New York: DK Publishing, 2002), 376, 378 and commentary. Before the war 322 aircraft, mostly DC-3s, made up the commercial airline fleet. Transport versions increased the number of DC-3s by 11,000 and DC-4s increased by 1,600.

[3] Under the priority travel rules, Priority One was given to those with orders from the President, Priority Two for military pilots taking planes to the front, Priority Three for those traveling on business associated with the war, and Priority Four for military cargo. Solberg, *Conquest of the Skies*, 274-75, 323, 331.

[4] Ibid., 314, 323, 333, 334.

Transcontinental Flight

During this postwar aviation boom, three big airlines fiercely competed over the coast-to-coast routes. American, United, and Transcontinental and Western Air (TWA) held transcontinental rights that Postmaster Walter Brown had planned for them. The 2,500-mile route was economically beneficial for the airlines, as well as popular with passengers who preferred it to auto or rail travel. But while the Douglas DC-3 was indispensable in the immediate postwar years, it still took 16 to 20 hours to travel cross-country. Thus, the airlines began looking for a more advanced airliner, one with more passenger capacity and longer range.[5]

The Douglas DC-4, the "overseas workhorse of World War II," met this demand. The DC-4 program had been begun for United Airlines, four other major airlines—American, Eastern, Pan American, and TWA—jointly approached Douglas prior to the war to assist in development costs. After the war, the DC-4 "set the standard of performance that became the basis for all airline flying." It reduced coast-to-coast travel time to 13 or 14 hours, and for the first time, the plane could still fly even if two engines failed.[6] American Airlines initiated transcontinental Douglas DC-4 service in March 1946.[7]

At the same time, TWA was banking its reputation on more advanced aircraft under the influence of its owner/majority shareholder, Howard Hughes. TWA put the new Lockheed Constellation into service on its coast-to-coast route on March 1, 1946.[8] The new triple-tailed aircraft, much ballyhooed for its beautiful design, had four of the biggest engines used during World War II, the Wright 3350. The first Lockheed Constellation, the L-049 model, "could climb to 25,000 feet, cruise at 280 miles per hour, and fly substantially farther than any previous airliner."[9]

The battle to obtain the most advanced equipment continued into 1952 when United and American began using the DC-6 aircraft, essentially a "stretched" version of the DC-4. TWA's Lockheed L-1049 Super Constellation featured 35 percent more passenger capacity and 40 percent more payload than its predecessor. With the aircraft's added range capability, TWA inaugurated the first transcontinental service between Los Angeles and New York on October 19, 1953. Competing with TWA's transcontinental route, American Airlines used the DC-7 with its

[5] R. E. G. Davies, *Airlines of the United States since 1914*, rev. ed. (Washington, DC: Smithsonian Institution Press, 1982), 328-29; Asif Siddiqi, "American Airlines," U.S. Centennial Commission, http://www.centennialofflight.gov/essay/Commercial_Aviation/American/Tran15.htm (accessed March 5, 2004); Bill Yenne, *Classic American Airliners* (St. Paul: MBI, 2001), 11. Northwest became a fourth transcontinental carrier in December 1944. Davies, *Airliners of the United States*, 332.

[6] Solberg, *Conquest of the Skies*, 313; Yenne, *Classic American Airliners*, 329. TWA and Pan American later pulled out from the DC-4 consortium to work toward the Boeing 307 Stratoliner. Yenne, *Classic American Airliners*, 13.

[7] Siddiqi, "American Airlines." American was also the first airline to offer pressurized-cabin service when it introduced its DC-6 on the New York–Chicago route.

[8] Asif Siddiqi, "Trans World Airlines (TWA)," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Commercial_Aviation/TWA/Tran14.htm (accessed March 5, 2004).

[9] Ibid.; Solberg, *Conquest of the Skies*, 310, quote on 311. The Constellation was originally designed for TWA as a non-stop transcontinental airliner, but was interrupted by the war when aircraft production was directed to the military (designated C-69). The first commercial type began with the L-649 that later developed into the L-1049 Super Constellation. Smithsonian National Air and Space Museum, "Lockheed 1049 (C-121C): Super Constellation," http://www.nasm.si.edu/research/aero/aircraft/lockheed_1049.htm (accessed August 11, 2004).

high-powered turbo-compound engines, a cruising speed of 330 miles per hour, and 58-passenger capacity.[10]

Transoceanic Flight

A major turning point for transatlantic passenger service came in June 1945. The Civil Aeronautics Board (CAB)—the authority that regulated both the entry of new airlines into the market and the setting of fares—granted three airlines permission to operate service across the North Atlantic: American Export Airlines (a shipping company) to northern Europe, Pan American to central Europe, and TWA to southern Europe. Thus, Pan American's monopoly over international air travel came to an end.[11] In October 1945, using the DC-4, American Export became the world's first airline to offer regularly scheduled landplane commercial flights across the North Atlantic. Early routes usually required refueling stops in Canada, Iceland, Ireland, and the United Kingdom, before continuing on to the Continent.[12] The next era in transatlantic air travel came with nonstop services on planes like the Douglas DC-7C (the Seven Seas) and Pan American's nonstop flights on the new Constellation aircraft. In 1957, the last of the Constellations, the L-1649A Starliner, was put into service. Now passengers could fly nonstop between New York and every West European capital. If it had been introduced earlier, the Starliner would have reigned supreme. However, within three years of its introduction, the aircraft became essentially obsolete when major airlines switched from propliners to jets.[13]

The next entry in the postwar air race was the Boeing 377 Stratocruiser. Prior to the war, in 1938, Boeing had introduced the Model 307 Stratoliner, the first airliner with a pressurized cabin to go into service in the United States. The creation of "a capsulized environment," states one historian, "in which passengers could ride in comfort through air too thin to breathe, was an American achievement."[14] Pan American and TWA flew the only ten 307s built. During the war, Boeing had produced the Model 367 as a transport carrier; this later became the commercial Model 377. Designed for Pan American and following in the tradition of luxury set by its prewar flying boats, the 377 was "[p]erhaps the ultimate in postwar airline travel." Pan American placed the first orders in 1945 and four test aircraft debuted between 1947 and 1948. In January 1949, Pan American received the fifth Model 377. Named *Clipper America,* the plane began service on the San Francisco to Honolulu route in April. Flexible seating allowed for over 100 passengers with spacious leg and headroom. A spiral staircase to the bar/lounge on the lower deck created "a sensation for early postwar airline travelers."[15]

Only fifty-five 377s were built, with the last delivery made in April 1950. Operating costs and reliability plagued the aircraft. At $1.75 million, the planes cost almost twice as much to operate

[10] Siddiqi, "Trans World Airlines"; Davies, *Airlines of the United States,* 333-34. In 1950, the airline officially changed its name to Trans World Airlines, but kept its old acronym.
[11] Asif Siddiqi, "The Beginnings of Commercial Transatlantic Services," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/Essay/Commercial_Aviation/Atlantic_route/Tran4.htm (accessed March 5, 2004); Solberg, *Conquest of the Skies,* 290.
[12] Bilstein, e-mail message to author, November 2004.
[13] Robert Serling, *The Jet Age* (Alexandria, VA: Time-Life Books, 1982), 12; Yenne, *Classic American Airliners,* 51.
[14] Quote, Solberg, *Conquest of the Skies,* 380; Yenne, *Classic American Airliners,* 55.
[15] Yenne, *Classic American Airliners,* 54-57; quotes, Roger E. Bilstein, *Flight in America: From the Wrights to the Astronauts*, 3rd ed. (Baltimore: The Johns Hopkins University Press), 172.

as the Lockheed Constellation and the Douglas DC-6 at $1 million.[16] Stratoliner engines were "balky and troublesome," and subject to frequent failure. Three stratocruisers crashed in the first four years of service, and four well-publicized crashes in the Pacific between 1955 and 1957 "marked the public relations turning point for the aircraft." Another three Pan American stratocruisers crashed between 1958 and 1959. With the advent of the jet age, major airliners sold their stratocruisers to secondary operators such as Transocean Airlines which operated between Hawaii and the U.S. West Coast.[17]

By the late 1940s, airline competition and the larger Douglas and Lockheed aircraft had made flying affordable to the general public. In the postwar years, a round-trip airfare had cost at least $700. At Juan Trippe's encouragement, the transatlantic carrier introduced a tourist-class fare bringing the cost of a New York to London trip to $487.[18] Trippe would later rank lowered airfares as "the third major milestone of airline history," along with Lindbergh's flight and the arrival of the jet age. Rather than vying for Pullman passengers, airlines could now tempt the railroad's coach business with their own "air coach." Even TWA, the "self-styled 'airline of the movie stars'," offered transcontinental coach flights in what a pilot described as "cattle class." Within a decade after World War II ended, millions flew each year, compared to the thousands of people who flew in the 1930s. Passengers now reflected a cross section of American society as ordinary people now booked flights.[19]

Increased revenues generated by the postwar propliners led to two milestones in the 1950s. In 1950, airlines began to fly free of airmail subsidy, and, in 1955, domestic airlines outpaced the railroad in passengers carried. The "golden age" of the propliner had dramatically changed the aviation industry. "But the 1950s propliners represented a technology that had been pushed as far as it would go."[20]

[16] Grant, *Flight,* 380.
[17] Pan American and Northwest traded certain stratocruisers to Boeing and Lockheed toward purchase of a Model 707 jetliner and L-188 Electras. Yenne, *Classic American Airliners,* 60-63.
[18] T. A. Heppenheimer, *Turbulent Skies: The History of Commercial Aviation* (New York: John Wiley & Sons, 1995), 192.
[19] Quote, Solberg, *Conquest of the Skies,* 345-46; Bilstein, *Flight in America,* 176.
[20] Solberg, *Conquest of the Skies,* 346, 349; quote, Grant, *Flight,* 380.

AIRPORTS

The Federal Airport Act of 1946

World War II had set a precedent for both direct federal aid for airports and significant improvements to airports in cities across the nation, especially those on the coasts and in the South. By the end of the war, many cities had improved facilities and were thus better prepared to meet the expansion of civilian air travel. City officials worried about the future of federal funding for major airports and lobbied for a more permanent federal aid program. These efforts resulted in the Federal Airport Act of 1946.

Several factors helped shape the act. First, the act favored the construction of smaller airports. This reflected the boom in private flying predicted by many for the postwar period. Second, debates over the relationship between cities and the federal government shaped how funds were distributed. And finally, although supporters sought to divorce airport aid from work relief and national defense, they were only partially successful.

The point of contention over aid allocated to smaller versus larger airports centered on the federal matching contribution. The law directed that 50 percent of funds, to be matched by local contributions, go to smaller Class 1, Class 2, and Class 3 airports. Larger Class 4 and Class 5 airports received the other 50 percent, but the act placed important limitations on the matching funds. Projects at the larger Class 4 and Class 5 airports could receive a 50 percent match on construction projects, however, the 50 percent match only applied to projects costing up to $5 million. For every additional $1 million spent, the federal match decreased by 5 percent. For projects costing more than $11 million, federal matching funds were set at 20 percent.[21] Though the formula changed over the years, nearly half of the funds available through this program went to smaller airports.

The Federal Airport Act allowed any local government to apply for aid. During the 1930s, cities had begun to develop stronger and more direct ties to the federal government.[22] Representatives of state governments argued that airport aid should not go directly to cities, but through state agencies to cities, thus reestablishing the traditional mediator role of states. When the act passed in 1946, a few states had passed laws requiring cities to apply for federal airport aid through a state agency. The following year, the Council of State Governments created a model bill "that [prohibited] direct federal grants to municipalities for airports and [required] the channeling of all such grants through state agencies."[23] Despite strong opposition from the American Municipal Association, 21 states had enacted legislation by 1949 that increased state control over federal airport aid.[24]

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[21] "T. P. Wright Announces 1947 Airport Allotments," *Airports* 11 (February 1947): 19. The CAA's classification system, published in 1944, sorted out airports primarily based on runway length. A Class 1 airport had runways 1,800-2,700 feet in length; Class 2, 2,700-3,700; Class 3, 3,700-4,700; Class 4, 4,700-5,700; and Class 5, 5,700 or longer.

[22] Mark I. Gefland, *A Nation of Cities: The Federal Government and Urban America, 1933-1965* (New York: Oxford University Press, 1975): 3-70.

[23] "States Would Control Federal Airport Grants," *National Municipal Review* 36 (January 1947): 35-36.

[24] John R. M. Wilson, *Turbulence Aloft: The Civil Aeronautics Administration amid Wars and Rumors of Wars, 1938-1953* (Washington, DC: U.S. Dept. of Transportation, Federal Aviation Administration, 1979), 175-80.

When the Civil Aeronautics Administration (CAA) first proposed its federal airport aid program in 1944, it justified the program on a number of grounds, including work relief and national defense. As the end of the war neared, many feared a return of Depression conditions. The CAA argued that airport construction "met all criteria for useful public works" and would help create jobs. By the time the bill passed in 1946, the postwar period seemed to promise more boom than bust. As prosperity returned, Congress felt little obligation to fully fund a program aimed at job creation.[25]

The CAA also argued that an airport construction program would aid national defense. However, in making that argument, the CAA focused not on the larger airports, but the smaller ones, built for general aviation. The CAA insisted that those smaller airports enhanced national defense by supporting the aircraft manufacturing industry. The expected postwar boom in private flying depended upon cities providing smaller airports serving light aircraft. In the post-war period, "private aviation" became known as "general aviation," a sector that emerged, according to Roger Bilstein, "as a significant element in the framework of American aeronautics." The nation now boasted nearly 350,000 pilots and the general aviation community anticipated an unprecedented demand for private aircraft. Their hopes were fueled by low prices stemming from both mass-production techniques learned during the war and a new generation of citizens acclimated to the possibility of air travel. Airports would promote the health of aircraft manufacturers by helping to support demand for light aircraft. This argument had several weaknesses, not the least of which was the fact that the firms building the larger planes required by the military for national defense were not the same firms building small, private aircraft.[26]

The final legislation made some reference to national defense, but it did not emphasize it. However, over subsequent years it became clear that federal funding leaned toward supporting airports that clearly and directly aided national defense. The Federal Airport Act of 1946 created a seven-year, $500-million program. Though the act authorized Congress to spend up to $71 million per year through the 1950s,[27] Congress failed to fully fund the program. In 1947, Congress appropriated only $42.75 million; that appropriation dropped to $30.4 million in 1948. Spending rose somewhat in 1949 and 1950, but it had dropped again, to $10.2 million, by 1953. During the Korean War, Congress again appropriated $500 million for improvements at airports with military use.[28]

World War II had demonstrated the need for a federal airport aid program established by the Federal Airport Act of 1946. This program anticipated the growth of aviation, commercial and general, in the postwar period. Although the situation was more fluid when it came to smaller airports, most of the major airports (or the air bases from which they would evolve) were in place by 1945. Very few cities built completely new, major airports after World War II. Exceptions included Dallas and Forth Worth, Texas (a joint airport); Kansas City, Missouri; Houston, Texas; Washington, D.C.; and Denver, Colorado. The complexity and cost of building these airports made prewar airport construction seem simple by comparison as the postwar period witnessed several challenges. The use of airport authorities became more common and the emergence of

[25] Ibid., 174.
[26] Ibid., 174-75; Bilstein, *Flight in America*, 60.
[27] In 1950, Congress voted for the first extension of the program, changing it from a seven-year to a twelve-year program.
[28] Wilson, *Turbulence Aloft*, 186-87, 191.

what eventually became the environmental movement presented airports with complex difficulties.

Airports and the Environment

In 1947, attorney Henry G. Hotchkiss predicted that noise complaints would pose a major challenge to airport operators and operations in the postwar era. Hotchkiss' article in *Aero Digest* focused on a U.S. Supreme Court case, *United States v. Causby* (1946). This case involved an airport used by military planes near Greensboro, North Carolina. The plaintiffs owned land near the airport, with their barn located 2,220 feet from the end of the runway and their house located 2,275 feet from the end of the runway. The military planes landing at the airport passed only 67 feet above the house. The owners also claimed not only that the flights made them nervous and frightened, but that the noise and nighttime landing lights from the aircraft forced them to close their chicken business; they were losing as many as 6 to 10 chickens a day when the terrified birds ran themselves into the wall of their coops.[29]

The Supreme Court decision, written by Justice William O. Douglas, upheld the idea that "the air [was] a public highway" and, therefore, the flights did not represent a trespass. However, the opinion also declared that "if the flight over the property rendered it uninhabitable, there would be a taking compensable under the Fifth Amendment." It also "found that there was, in fact, a partial taking." Since the flight operated directly over the plaintiffs' property, "the land [was] appropriated as directly and completely as if it were used for the runways themselves."[30]

The court then more precisely defined navigable airspace, distinguishing it from the airspace used by aircraft over the plaintiffs' property. Federal law defined navigable airspace "as that 'above the minimum safe altitudes for flight'," the precise altitude determined by the operational limits of the aircraft. It further set the minimum safe altitude for air carriers as 500 feet above ground level (AGL) during the day and 1,000 feet AGL at night. For other aircraft the minimum was 300 feet AGL during the day and 1,000 feet AGL at night. Though the court declined to set a clear limit between navigable and non-navigable airspace, it ruled that the aircraft flying over the plaintiffs' property were not in navigable airspace, hence, the noise and glare produced represented a taking.[31]

Hotchkiss noted that the decision posed the greatest danger for private airports as public airports could generally exercise the power of eminent domain, acquiring private property with compensation to the owner. Private airports did not have that option.[32] Though private airports faced the greater risk, noise complaints against public airports soon became ubiquitous. The issue gained widespread attention in the early 1950s following a series of air disasters in the New York City area. On December 16, 1951, a Miami Airlines C-46 crashed in nearby Elizabeth, New Jersey, after fire erupted in its right engine, killing all 56 aboard. In January 1952, an

[29] Henry G. Hotchkiss, "Airports before the Bench," *Aero Digest* 55 (August 1947): 37; *United States v. Causby*, 328 U.S. 256 (1946).
[30] Ibid.
[31] Ibid., 37, 119.
[32] Ibid., 120, 122. For a discussion of the evolution of court decisions concerning noise at public airports, see Lyman M. Tondel, Jr., "Noise Litigation at Public Airports," in *Alleviation of Jet Aircraft Noise near Airports: A Report of the Jet Aircraft Noise Panel*, Office of Science and Technology, Executive Office of the President (Washington, DC: Government Printing Office, March 1966), 117-31.

American Airlines flight hit a six-story building less than1 a half mile from the December crash site, killing 29 people, including six on the ground. Then, on February 10, a DC-6 crashed on takeoff from the Newark airport, killing 27 people on the plane and four on the ground. In response, the Newark airport temporarily closed. The closure of the airport led to increased flights at other regional airports, and local residents began to complain. Their concerns skyrocketed when in April a C-46 crashed while attempting to land at Idlewild, killing the crew and three people on the ground. Some demanded that both Idlewild and LaGuardia be closed. Though the public hysteria died down, C. E. Rosendahl, a member of the National Air Transport Coordinating Committee, concluded in a paper presented at the Society for Automotive Engineers' National Aeronautic Meeting in April 1954, that the fear created in the wake of the New York–Newark accidents had "served to crystallize…already existing and mounting resentment against air terminals and their air operations."[33] Much of that resentment focused on noise.

Both the federal government and the airlines took action in the wake of these accidents. In February 1952, President Harry S Truman appointed an Airport Commission, headed by famed aviator James "Jimmy" Doolittle, to investigate the issues raised by airport location and use. Within 90 days the commission issued its report, *The Airport and Its Neighbors*. The report acknowledged attempts to reduce noise begun under CAA sponsorship, but held that long-term noise complaints were unlikely to abate, especially given the anticipated introduction of civilian jet aircraft. The commission called for a better outreach campaign to educate the public on airport operations and to work with the airlines to revise flight procedures near airports. It also called for federal aid so that communities could build longer runways and create secure cleared zones off the ends of those expanded runways. Other suggestions included the construction of single or parallel runways to minimize the areas affected by flight operations, renewed research into crosswind landing gear, and the use of federal airport funds to encourage cities to improve their local community and airport planning, including zoning.[34]

The airlines responded with the formation of the National Air Transport Coordinating Committee (NATCC). Though it focused primarily on the problems facing the New York region, committee members understood that its solutions could be applied nationwide. During VFR (visual flight rules) conditions, pilots were instructed to maintain an altitude of 1,200 AGL for as long as possible prior to landing and they were encouraged to climb to that same altitude as soon as possible after takeoff. The committee also recommended the use of preferential runways—runways oriented to minimize operations over residential areas—as much as possible. To address New York's specific problems, the committee also worked to move training operations away from the region, reducing takeoffs and landings by 25,000 per year. Finally, the NATCC inaugurated a public information campaign.[35] In addition, in 1952 the CAA and its successor organization, the Federal Aviation Administration (FAA), began what became a long-term research program on aircraft noise. Though focused on the noise caused by piston-engine aircraft, research on noise created by jet aircraft began in 1955.

[33] Wilson, *Turbulence Aloft*, 259-64; C. E. Rosendahl, "Aircraft Noise Problems in Airport Vicinities," *SAE Transactions* 65 (1955): 289-90.
[34] Wilson, *Turbulence Aloft*, 262-64.
[35] Rosendahl, "Aircraft Noise Problems," 290-94.

Airport Architecture

Although a number of "signature" designs emerged in the United States before World War II, the postwar period witnessed the construction of several widely acclaimed terminals. One terminal that received particularly wide acclaim prior to the introduction of jets was that in St. Louis. In the early 1950s, the city of St. Louis contracted with Hellmuth, Yamasaki and Leinweber to design a new terminal to replace Lambert Field's (now Lambert-St. Louis International Airport) original facility, built in 1927. The architects had a number of issues to address in their design. First, the new terminal had to be "a visually significant place of arrival and departure, easily seen from approaching automobiles and airplanes." Second, city leaders wanted their terminal to have interior space that "provide[d] a vantage point from which the activities of a busy airfield could be observed without the room itself being rendered insignificant." Finally, the design had to allow for expansion.[36] The building, completed in 1956, has been judged a "stunning achievement." The terminal consisted of "three pairs of intersecting barrel vaults made of concrete, four inches thick and sheathed with copper." The design included walls of windows, a main level (where passengers entered the airport) and two lower levels holding "all service and traffic facilities." The lower floors included "closed corridors" that led passengers "to within a few feet of waiting planes." Observation decks were built on the roofs of these corridors.[37] The architectural design firm (and its successor Hellmuth, Obata and Kassabaum) quickly emerged as a major player in airport terminal design around the world. And with its separation of "arriving and departing passengers on different levels… . [it] was a precursor of terminal design in the 1960s." [38]

[36] *Buildings for Business and Government* exhibit program (Museum of Modern Art, February 25-April 28, 1957): 30, Series One, Box 25, File: Lambert-St. Louis Municipal Airport, Special Collections and Archives, Raymond A. Tucker Papers, Washington University of St. Louis, St. Louis, MO.
[37] Ibid.; John Zukowsky, ed., *Building for Air Travel: Architecture and Design for Commercial Aviation* (New York, Munich and Chicago: Prestel-Verlag, 1996), 133.
[38] Geza Szurvoy, *The American Airport* (St. Paul: MBI, 2003), 114.

GROUND-BASED AIRWAY

Airline travel in the first decade after World War II began to overtake ocean liners and rail traffic in popularity. More air traffic sparked a need for safer airways and better landing systems. In the 1940s and 1950s the CAA, the federal agency responsible for airway development and safety enforcement, tested radar and landing systems. Important innovations included the very high frequency omnidirectional range (VOR), the ground-controlled radar system, and the instrument landing system.

Very High Frequency Omnidirectional Range

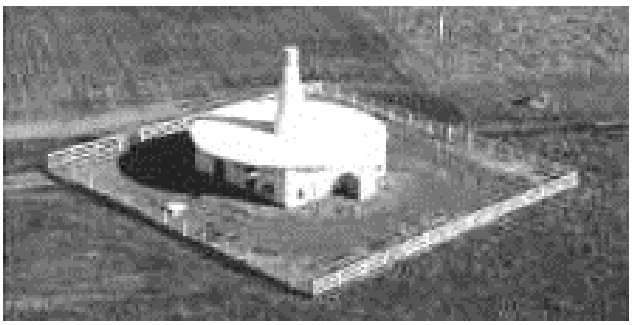
In 1944, the CAA began testing the very high frequency omnidirectional range (VOR) at its Technical Development Center located adjacent to the Indianapolis Municipal Airport in Indiana. Also known as the Experimental Station, this facility had opened on May 29, 1939, with a mission to improve aviation safety through ultra-high-frequency radio ranges, transmitters, receivers, instrument landing systems, airport lighting methods, and other air navigation aids. CAA facilities included a hangar, laboratory, and shop building. The Experimental Station was the center for developing air navigation aids until the late 1950s when it was gradually deactivated.[39]

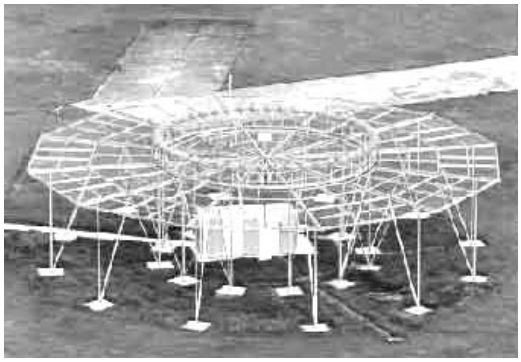
The Indianapolis Experimental Station showing the CAA's first radar-equipped control tower for civilian flying unveiled in 1946. Source: FAA at U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/Essay/ Government_Role/FAA_History/POL8G3.htm

In 1946, the CAA converted eight four-course radio range stations on the New York–Chicago airway to VOR stations on an experimental basis, and the system was later adopted as its standard for navigation.[40] A VOR emits signals in the pattern of a huge wheel, with the station at the center and 360 spokes radiating from the hub. Each radial represents a radio course that a pilot can use to accurately guide an airplane along a desired track. Thus, the VOR sends signals in all directions from the station, instead of merely four courses. VOR also allows a pilot to navigate using a dial on the instrument panel in the cockpit, as opposed to listening to a radio signal. This system was a vast improvement over the aural signals of the four-course ranges of the 1930s and 1940s.[41] VOR airways, known as Victor airways, supplemented the 70,000 miles

[39] Charles Wood, "The Instrument Landing System," Flight Simulator Navigation, http://www.navfltsm.addr.com/ils.htm (accessed June 14, 2005); Federal Aviation Administration, "FAA Historical Chronology, 1926-1996," http://www.faa.gov/about/media/b-chron.pdf (accessed June 2, 2005). In 1958, the new National Aviation Facilities Experimental Center (NAFEC) near Atlantic City, New Jersey, was established and many of the resources and personnel from the Experimental Station were transferred there.
[40] Federal Aviation Administration, "FAA Historical Chronology;" Heppenheimer, *Turbulent Skies*, 173.
[41] Federal Aviation Administration, "Building the Airways," http://www.faa.gov/about/history/photo_album/

of federally maintained low-frequency airways. The CAA and the FAA shut down the low-frequency four-course radio ranges, and improved upon the VOR technology. The first Doppler VOR, used where standard VOR could not be used, was commissioned by the FAA for service at Marquette, Michigan, on June 29, 1961.[42] Because Doppler VOR is based on the Doppler effect, in which motion changes a sound wave's perceived frequency, the Doppler VOR is more practical in crowded areas or around tall buildings.[43]





A VOR (above) and Doppler VOR station (right). Sources: Federal Aviation Administration; Southgate Amateur Radio Club

Ground-Controlled Radar System

In 1947, the CAA tested a ground-controlled approach (GCA) radar system at Washington National Airport, Chicago Municipal Airport, and New York's LaGuardia Airport.[44] GCA radar enables air traffic control personnel to transmit instructions to the pilot by radio, "talking aircraft down" during the final phase of descent. It also gives airports increased operational effectiveness through better all-weather capability by permitting landings at lower ceilings and visibility.[45] Although originally developed for the military, GCA radar was modified for civilian use, then loaned to the CAA by the Army Air Forces, and installed at airports by the Airborne Instrument Laboratory of the Air Transport Association. On February 4, 1949, the CAA granted authorization for commercial planes to use GCA radar as a primary aid for landing in poor weather. At LaGuardia, the use of GCA tripled the landing rate to 15 airplanes per hour.[46] Washington National Airport was also the testing ground for microwave early-warning (MEW) radar, one of the best long-range devices developed during the war.[47]

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foundation/index.cfm?cid=building (accessed June 2, 2005); Federal Aviation Administration, Southwest Region Logistics Division, "Air Navigation and Air Traffic Control," http://www.faa.gov/asw/asw050/nav.html (accessed June 13, 2005); Federal Aviation Administration, "FAA Historical Chronology"; Bilstein, *Flight in America*, 178.

[42] Federal Aviation Administration, "FAA Historical Chronology."

[43] Southgate Amateur Radio Club, "Doppler VOR," http://www.southgate.org/articles/vor.htm (accessed June 16, 2005).

[44] Federal Aviation Administration, "FAA Historical Chronology."

[45] Pilot's Web, "Aviation Terms," http://www.pilotsweb.com/pcg/pcgg.htm (accessed June 20, 2005); U.S. Air Force, National Museum of the United States Air Force, "AN/FPN-16 Precision Approach Radar and Shelter," http://www.wpafb.af.mil/museum/vfe/vfe12.htm (accessed June 20, 2005).

[46] IEEE Virtual Museum, "Air Traffic Control and Radar," http://www.ieee-virtual-museum.org/-collection/tech.php?taid=&id=2345899&lid=1 (accessed June 20, 2005).

[47] Federal Aviation Administration, "FAA Historical Chronology."

Instrument Landing System

By the mid-1950s, the GCA landing system was being replaced by the Instrument Landing System (ILS), which had been developed in the late 1920s, but had seen limited use. The airlines argued that this system was not flyable, partly because of the expense entailed in installing the necessary instruments in the aircraft, and partly because of safety concerns. The system uses receivers in aircraft that display course deviation directly to the cockpit. Because the pilot must fly within close range of the ILS ground-based equipment, it can be used only a short distance from the airport. This system helps a pilot land an airplane when the runway cannot be seen due to limited visibility.[48]

ILS was first demonstrated by Lt. Jimmy Doolittle at Mitchel Field on September 24, 1929. Doolittle's biplane used an Aircraft Radio Corporation (ARC) radio range receiver, which enabled the first "blind" flight. Accompanied by a safety pilot, Doolittle took off and flew a prescribed course. Without being able to see outside the cockpit, he then landed using instruments only. "It was," states aviation historian Tom Crouch, "the beginning of the end for seat-of-the-pants flying." ARC had been incorporated in 1927 as a division of the Radio Frequency Labs of Boonton, New Jersey, to develop airborne receivers for the CAA's low-frequency navigation ranges. The ARC Airfield in Boonton Township developed, manufactured, and tested the first radio equipment for aircraft.[49]

ILS was not widely adopted until 1928 when a group of engineers in the Bureau of Standards developed the base for a modified version called air track. The first landing of a scheduled U.S. airliner using air track was on January 26, 1938. Using only the air track system, a Pennsylvania Central Airlines Boeing 247-D carried passengers from Washington, D.C., to Pittsburgh, Pennsylvania, and landed in a snowstorm. In 1939, an ILS unit was installed at the Indianapolis Municipal Airport and extensively and successfully tested in a variety of conditions. The CAA then authorized the installation of ILS at additional locations. By 1945, nine such systems were in operation and ten additional locations were under construction. Another 50 were being installed for the army, which modified the blind landing system. The army also introduced an ILS with a higher-frequency transmitter to reduce static and create straighter courses called the Army Air Forces Instrument Approach System or Signal Corps Set 51. In 1949, the International Civil Aviation Organization adopted this army standard for all member countries.[50]

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[48] Roger Mola, "Aircraft Landing Technology," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Evolution_of_Technology/landing_navig/Tech32.htm (accessed June 30, 2005). A glide-slope receiver for guidance of the aircraft in the vertical plane and a marker-beacon receiver in the plane show the pilot whether the airplane is to the right or left of the centerline and whether it is above or below the glide slope. U.S. Centennial of Flight Commission, "Instrument Landing System," http://www.centennialofflight.gov/essay/Dictionary/ILS/DI87.htm (accessed June 30, 2005).

[49] Crouch, *Wings*, 237-38. Doolittle received the Harmon Trophy for his achievement. Pamela Feltus, "Jimmy Doolittle—Aviation Star," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Air_Power/doolittle/AP17.htm (accessed June 30, 2005); Paul Freeman, "Aircraft Radio Corporation Airfield, Boonton, NJ," Abandoned and Little-Known Airfields, http://www.airfields-freeman.com/NJ/Airfields_NH_NW.htm#aircraftradio (accessed June 30, 2005).

[50] Roger Mola, "History of Aircraft Landing Aids," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Government_Role/landing_nav/POL14.htm (accessed June 30, 2005).

The Federal Aviation Act of 1958

The approaching introduction of jet airliners and a series of airplane crashes in the 1950s highlighted the need for increased government regulation of air routes and modernization of the air traffic control system leading to the passage of the Federal Aviation Act. The most notable of these aviation disasters occurred on June 30, 1956, when two of the largest commercial aircraft then in service, a United Airlines DC-7 and a TWA Super Constellation collided [Crash Site] over the Grand Canyon in Arizona killing all 128 people aboard the two aircraft. Traveling eastward from Los Angeles International Airport toward the Painted Desert, both planes were flying in uncontrolled airspace under visual flight rules (VFR), which assumed that a pilot could see other aircraft and that separation of aircraft would be maintained on a "see and be seen" basis. However, the weather that day was overcast with some showers. The TWA pilot requested an increase in altitude from the Los Angeles and Salt Lake City Air Traffic Control Centers, hoping to fly above the poor weather. Tragically, the paths of the two aircraft crossed at 21,000 feet, resulting in the worst U.S. airline disaster up to that time. In its accident investigation report, the Civil Aeronautics Board (CAB) concluded that the pilots' inability to see each other in time to avoid the collision probably caused the collision. After the accident, commercial aircraft became equipped with collision avoidance radar.[51]

In response to the crash, Congress passed the Airways Modernization Act of 1957 that established a board responsible for "the development and modernization of the national system of navigation and traffic control facilities." The act, however, was repealed a year later, just as the Air Commerce Act of 1926 and the Civil Aeronautics Act of 1938 were by passage of the Federal Aviation Act of 1958. The Federal Aviation Act comprehensively covered the federal role in fostering and regulating civil aeronautics and air commerce. The legislation gave the Civil Aeronautics Authority's (CAA) functions to a new independent body, the Federal Aviation Agency, transferred safety rule making from the CAB to the new FAA, and gave the FAA sole responsibility for a common civil-military system of air navigation and air traffic control.[52]

[51] John Carr, speech, International Society of Air Safety Investigators seminar, National Air Traffic Controllers Association, http://www.natca.org/mediacenter/speechdetail.asp?id=235 (accessed June 17, 2005); Emily Chang et al., "Notable Collisions," http://mit.edu/6.933/www/Fall2000/mode-s/collisions.html#1956, Massachusetts Institute of Technology (accessed June 21, 2005).

[52] Edmund Preston, "The Government Role in Civil Aviation—An Overview," U.S. Centennial of Flight Commission, http://centennialofflight.gov/essay/Government_Role/POL-OV.htm (accessed June 17, 2005).

RESEARCH & DEVELOPMENT

During the 1940s and 1950s, high-altitude scientific balloon flights made possible by the plastic balloon, dominated the field of lighter-than-air aviation. Collaborations between pioneering scientists, the navy, and the National Aeronautics and Space Administration (NASA) significantly enhanced cosmic ray research and the feasibility of putting a person into space. Projects *Excelsior, Helios, Skyhook*, and *Strato-Lab* became important government initiatives.

The Era of the Plastic Balloon[53]

Following World War II, the General Mills company became a major player in balloon research. During the war, General Mills had diversified beyond foodstuffs to secure more government contracts, and established an engineering, research, and development department. The department's staff of 2,000 developed precision optical and mechanical devices for fire control and aeronautics. At war's end, General Mills established an Aeronautical Research Laboratory in hopes of securing postwar military contracts.[54]

An entire department was specifically dedicated to high-altitude balloon work. Renowned aeronautics expert Jean Piccard, along with Otto Winzen, who would became a central figure in reviving high-altitude scientific balloon flights, were employed there. Work first commenced in a wartime bombsight laboratory at General Mills in Minneapolis, Minnesota. Later, during the late 1940s, the company housed its balloon activities in the Whitney School building in Minneapolis. In 1951, the company moved its operations to the fourth floor of the Fulton Bag Building (Plant 5). Eventually the engineering, research, and development department occupied all five floors until August 1963. In October 1955, additional balloon manufacturing facilities moved into the Griggs-Cooper Building (Plant 7) in St. Paul, Minnesota. Unprecedented growth in 1956 placed the plastic balloon program's headquarters, with its administrative, flight operations, instrumentation, and engineering personnel in the new Truman Building (Plant 6) in Minneapolis.[55]

Project *Helios*

In December 1946, the Office of Naval Research (ONR) contracted with General Mills to construct plastic balloons for Project *Helios*. This program for high-altitude manned flight used a cluster of plastic balloons and was based on a concept Piccard had presented to ONR in February 1946, and which ONR approved on June 24, 1946.[56] Under *Helios*, 80 to 100 polyethylene plastic balloons would carry a sealed gondola up to 100,000 feet. At this time,

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[53] Portions of this section were excerpted from U.S. Centennial of Flight Commission, "Scientific Research Using Balloons in the First Part of the Twentieth Century," http://www.centennialofflight.gov/essay/Lighter_than_air/science-I/LTA14.htm (accessed February 17, 2004); and Linda Voss, "Balloons as Forerunners of Space Flight and Exploration," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/ Lighter_than_air/Balloons_and_Space/LTA17.htm (accessed February 17, 2004).

[54] David H. DeVorkin, *Race to the Stratosphere: Manned Scientific Ballooning in America* (New York: Springer-Verlag, 1989), 268.

[55] Harold E. Froehlich, former principle engineer for General Mills' Balloons and Meteorological Systems Group, telephone conversation with Caridad de la Vega, National Park Service, December 2004; John A. Wickland, "Firm Starts New Balloon Division," *Minneapolis Sunday Tribune*, May 20, 1956, article courtesy of Mr. Froehlich.

[56] National Aeronautics and Space Administration, "Aeronautics and Astronautics Chronology, 1945-1949," http://www.hq.nasa.gov/office/pao/History/Timeline/1945-49.html (accessed July 22, 2009).

"General Mills and the University of Minnesota were rapidly becoming the focal point for all U.S. balloon activity."[57]

On September 25, 1947, *Helios* was launched from St. Paul, Minnesota. The balloon had a capacity of 100,000 cubic feet, and carried 70 pounds of equipment. Out of four launches, only the first and fourth succeeded. On the fourth launch, the balloon refused to descend for three days and the high-altitude controls, radio equipment, and insulated containers malfunctioned. However, the delay proved beneficial for cosmic ray researchers. Two Brookhaven National Laboratory physicists had flown cosmic ray plates on the mission and were delighted with the results brought by the three-day delay. They told Winzen that it would take "years to analyze the wealth of cosmic ray events in these plates. "From that day on cosmic research and plastic balloons became inseparable."[58] Literally hundreds of cosmic ray instruments and photographic plates were carried aloft under polyethylene balloons. Many developments in aerospace science were made possible through the discovery of polyethylene, which produced a lightweight balloon and made manufacturing cost efficient. This discovery ultimately became a critical and determining factor for its use in the U.S. space program.[59]

Project *Skyhook*

The success of Project *Helios* led ONR to abandon the idea of manned balloon flights and focus on unmanned research. Unfortunately the project was stymied by both inoperable balloons and internal disputes between ONR and the Office of the Chief of Naval Operations. Ultimately, *Helios* was divided into an unmanned scientific military balloon program known as Project *Skyhook* in September and October 1947, and a manned high-altitude balloon project later known as Project *Strato-Lab*.[60] *Skyhook* was one of the first major programs to take advantage of the new balloon technology. On August 19, 1957, an unmanned *Skyhook* balloon lifted cargo from the Stratoscope project, a program developed through the National Center for Atmospheric Research (NCAR) with the cooperation and joint sponsorship of the National Science Foundation, the U.S. Navy, and NASA. The main instrument was a 12-inch telescope with a special light-sensitive pointing system and a closed-circuit television camera that researchers could guide, and which was the first balloon-borne telescope. Researchers took over 400 of the sharpest photographs taken of the sun up to that period, increasing their understanding of the motions seen in the sunspots' strong magnetic fields.

In 1952, another early cosmic ray researcher, Dr. James Van Allen of the University of Iowa, used an ONR grant to develop "rockoons:" balloons that carry sounding rockets launched from Earth with instruments to observe and measure various natural phenomena. Rockoons extend the altitude from which data could be collected. By launching the sounding rocket from a balloon at 70,000 feet, Van Allen could send instruments up to 300,000 feet to measure the energy in cosmic rays and the interaction of cosmic radiation with the Earth's atmosphere near the North Pole. As the rockets fell back into the atmosphere, they provided scientists with data on cosmic

[57] Craig Ryan, *The Pre-Astronauts: Manned Ballooning on the Threshold of Space* (Annapolis: US Naval Institute Press, 2003), 64; Edwin J. Kirschner, *Aerospace Balloons: From Montgolfière to Space* (Blue Ridge Summit, PA: Aero Books, 1985), 16; Quote, Tom D. Crouch, *The Eagle Aloft: Two Centuries of the Balloon in America* (Washington, DC: Smithsonian Institution Press, 1983), 641.
[58] Quote, Crouch, *Eagle Aloft*, 641.
[59] Kirschner, *Aerospace Balloons*, 16; Crouch, *Eagle Aloft*, 640.
[60] Ryan, *Pre-Astronauts*, 63-64; Crouch, *Eagle Aloft*, 640-41; DeVorkin, *Race to the Stratosphere*, 297.

rays, pressure, heat, and other conditions. These early experiments suggested the existence of trapped radiation in near-Earth space. Later confirmed by satellites, this trapped radiation became known as the Van Allen radiation belts. By the mid-1950s, balloon rockets were extensively launched from ships, polar sites, and sites in New Mexico.[61]

In 1948, Winzen, who had built balloons for Project *Skyhook*, left General Mills. The ONR contract for the production of plastic balloons transferred with him. He established his own company, Winzen Research in Minneapolis, through money procured by his wife, Vera Winzen, who served as vice-president and chief of production. During her 10 years with the company, Vera established herself as the "finest balloon builder in the world," obtaining four patents in the process. Overall, Winzen Research became one of the world's first plastic balloon companies and the balloon firm most involved with early manned flights. As the developer of the polyethylene resin plastic balloon and an innovator in balloon manufacturing, Otto Winzen's contribution to balloon technology was tremendous.[62]

Winzen Research and General Mills manufactured the balloons for Project *Moby Dick* initiated in 1956 by the U.S. Air Force Strategic Air Command and considered the most recognized of all the balloon reconnaissance programs.[63] On January 9, 1956, the air force publicly launched new plastic meteorological balloons from stations in Okinawa, Alaska, and Hawaii. Officially the balloons were for the study of wind currents and atmospheric conditions in the stratosphere. However, the program's real intent was aerial reconnaissance of the Soviet Union and China. A total of 516 balloons were launched from different locations throughout the United States and its European bases, with a central plotting facility located at Lowry Field [Lowry Air Force Base, NR, 2002] in Denver, Colorado. Balloon-borne cameras on the instrument packs that were retrieved recorded only about 8 percent of the Soviet Union and China. The Soviets eventually became aware of the balloons and publicly complained, forcing the air force to terminate its reconnaissance program.[64]

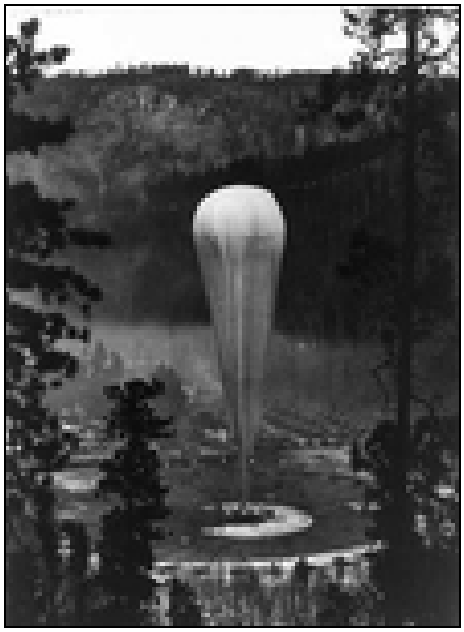
Project *Strato-Lab*[65]

On November 8, 1956, the Stratobowl, previously used to launch the high-altitude balloon flights of *Explorer I* and *II* in 1934 and 1935 respectively, hosted another balloon launch as part of Project *Strato-Lab*, a high-altitude manned balloon program established in 1954 and an offshoot of the failed 1947 *Helios* project. Project *Strato-Lab* undertook research for the manned rocket program. U.S. Navy Lt. Cdrs. Malcolm D. Ross and M. Lee Lewis broke the altitude record established by *Explorer II* when they reached 76,000 feet in a balloon named *Strato-Lab I*. Despite problems encountered during the mission, "the flight was a clarion call announcing that

[61] Kirschner, *Aerospace Balloons*, 17.
[62] Ryan, *Pre-Astronauts*, 67.
[63] Ryan, *Pre-Astronauts*, 68; Crouch, *Eagle Aloft*, 644.
[64] Crouch, *Eagle Aloft*, 644, 646-47; Ryan, *Pre-Astronauts*, 68-69; Elaine Gallagher Adams and Nancy Widmann, "Lowry Air Force Base," National Register of Historic Places Registration Form (Washington, DC: National Park Service, 2001), Section 8, pp. 13-14. The cover name for Project Moby Dick was White Cloud. Ryan, *Pre-Astronauts*, 68.
[65] Portions of this section were excerpted from U.S. Centennial of Flight Commission, "Higher, Farther, and Longer—Record Balloon Flights in the Second Part of the Twentieth Century," http://www.centennialofflight.gov/essay/Lighter_than_air/20th_cent_records-2/LTA12.htm (accessed February 17, 2004); and Voss, "Balloons as Forerunners."

the United States was now officially back in the business of exploring the stratosphere by means of balloon."[66]

The next record came within the high-altitude manned balloon program Project *Strato-Lab*. On May 4, 1961, U.S. Navy commander Malcolm Ross and Lt. Cdr. Victor Prather ascended in *Strato-Lab V* to 113,740 feet on a flight launched from the navy aircraft carrier USS *Antietam* in the Gulf of Mexico.[67] Space suits developed by the navy and tested on this flight became the prototypes for NASA's Mercury Program.[68] The achievement was marred, however, by Prather's death after he fell from the sling of the recovery helicopter and died on board the carrier. Their record remains unsurpassed to this day despite attempts by two British explorers in 2003.



Explorer II on the floor of the Stratobowl before its launch. Source: The Library of Congress, Prints and Photographs Division (LC-USZ62-70305)

Project *Excelsior*

Over the 20th century, the military set and broke more altitude and distance balloon records. In August 1957, air force surgeon Maj. David Simons climbed to a record 102,100 feet, remained aloft for 32 hours, and drifted 405 miles from his starting point. Three years later, on August 27, 1960, air force captain Joseph Kittinger, Jr., set a world record for the highest balloon ascent, reaching 102,800 feet in the *Excelsior III*, part of Project *Excelsior* launched from Holloman Air Force Base in Alamogordo, New Mexico. At the end of his ascent, Kittinger jumped from the gondola and parachuted to the ground, setting a record for the longest parachute free fall—4 minutes and 36 seconds—before his main parachute opened at 18,000 feet. His descent reached up to 614 miles per hour, approaching the speed of sound as he fell through air temperatures as low as -94° F. His flight and parachute jump show it was feasible to put a person into space and for fliers to exit aircraft at extremely high altitudes and free-fall back through the Earth's atmosphere.

Transatlantic Crossing

The dream of a transatlantic crossing in a balloon was finally realized on August 11, 1978. The *Double Eagle II* balloon carried Ben Abruzzo, Maxie Anderson, and Larry Newman across the Atlantic from Presque Isle, Maine, to a wheat field near Miserey, France, in 137 hours and 7 minutes. The 3,100-mile flight was the culmination of 17 previous attempts made by countless

[66] Ryan, *Pre-Astronauts*, 226, 228, quote on 230; U.S. Department of the Navy, Naval Historical Center, "Navy in Space Chronology, 1945-1981," http://www.history.navy.mil/faqs/faq124-1.htm (accessed September 28, 2004).
[67] The gondola for this flight is housed at the National Museum of Naval Aviation in Pensacola, Florida.
[68] Cdr. Ed Melton, "Twenty-Five Years of Skyhook," *Naval Research Reviews* 26, 5, courtesy of Mr. Harold Froehlich.

others since Wise and Donaldson made the first veritable attempt at a transatlantic crossing in 1873.[69]

[69] William H. Longyard, *Who's Who in Aviation History: 500 Biographies* (Shrewsbury, UK: Airlife Publishing, 1994), 9; Smithsonian National Air and Space Museum, "*Double Eagle II*," http://www.nasm.si.edu/research/aero/aircraft/double_eagle.htm (accessed February 19, 2004).

CHAPTER 15. THE JET AGE & DEREGULATION, 1954-1978

RESEARCH & DEVELOPMENT

The Era of the Jet Propelled Airplane

Breaking the Sound Barrier

The morning of Tuesday, October 14, 1947, dawned bright and beautiful over Muroc Dry Lake, a large expanse of flat, hard surface in California's Mojave Desert. At 6:00 a.m., teams of engineers and technicians at the Muroc Army Air Field began to prepare a small rocket-powered airplane for flight. Painted orange and resembling a 50-caliber machine-gun bullet connected to a pair of stubby wings, the Bell X-1 research vehicle was carefully installed in the bomb bay of a B-29 bomber. At 1:00 a.m., the B-29 took off and climbed to an altitude of 20,000 feet. As it rose past 5,000 feet, Capt. Charles E. "Chuck" Yeager, a veteran World War II pilot, struggled into the cockpit of the X-1. At 10:26 a.m., at a speed of 250 miles per hour, the X-1 dropped free from the B-29. Yeager then fired the rocket engine, and powered by 6,000 pounds of thrust, the sleek airplane accelerated and climbed rapidly. The X-1 soon exceeded Mach 0.85, the speed beyond which no wind-tunnel data yet existed. No one knew what problems might be encountered in transonic flight beyond the speed of Mach .85.

The Bell X-1, piloted by Capt. Charles E. "Chuck" Yeager, became the first aircraft to fly faster than the speed of sound. Source: Smithsonian National Air and Space Museum, http://www.nasm.si.edu/imagedetail.cfm?imageID=996

Upon entering this unknown realm, Yeager momentarily shut down two of the four rocket chambers and carefully tested the controls of the X-1 as the Mach meter in the cockpit registered 0.95 and continued to increase. At an altitude of 40,000 feet, the X-1 began to level off, and Yeager fired one of the two shutdown rocket chambers. The Mach meter moved smoothly to reach 1.02. There the meter hesitated and then jumped to 1.06. A stronger bow shock wave formed in the air ahead of the needle nose of the X-1 as Yeager reached a velocity of 700 miles per hour, Mach 1.06, at 43,000 feet. The flight was smooth; there was no violent buffeting of the airplane and no loss of control, as some engineers had feared. At that moment, Yeager became the first pilot to fly faster than the speed of sound, and the small, streamlined Bell X-1 became the first supersonic airplane in the history of flight.

As the sonic boom from the X-1 resonated across the California desert, that flight became the most significant milestone in the history of airplane technology since the Wright brothers' first flight at Kill Devil Hills 44 years earlier. Breaking the sound barrier—the process of accelerating through Mach 1 (the speed of sound) and going from subsonic to supersonic speeds—opened a new future for aviation, high-speed flight at and beyond the speed of sound. A second golden age of aeronautical engineering emerged, one that coincided squarely with the era of the jet-propelled airplane. This era had gestated in the 1930s, but the new breed of

high-speed airplanes powered by jet engines was born in 1945; its development continues to the present.

The Swept Wing

Today, airplanes with swept-back wings for both subsonic and supersonic flight are commonplace. The German aerodynamicist Adolf Busemann introduced the concept of the swept wing for high-speed flight at the 1935 Volta Conference in the presence of the world's leading high-speed aerodynamicists. Although a major breakthrough, this idea was virtually ignored by the audience. Even Eastman Jacobs, one of the leading scientists at NACA's Langley laboratory, and Dr. Theodore von Kármán, an eminent mathematician, scientist, and engineer who had emigrated from Germany to the United States, did not mention the idea on their return to the United States. Ten years later, as World War II ended and jet airplanes began to revolutionize aviation, Robert T. Jones, an ingenious aerodynamicist at Langley, independently suggested the idea of swept wings. When Jones presented his proposal to Jacobs and von Kármán in 1945, neither man remembered Busemann's idea from the Volta Conference. von Kármán mentioned that oversight in his autobiography, "I must admit that I did not give this suggestion much attention until years later." Unlike their American counterparts, the German Luftwaffe recognized the military significance of Busemann's idea and classified the concept in 1936, one year after the conference. By the end of the war, Germany's research program on swept wings had produced a mass of technical data. When Allied technical teams entered the German research laboratories at Pennemunde and Braunschweig in early 1945, they were surprised—and concerned—by the Germans' knowledge.

George Schairer, later a vice president of the Boeing Company, was a member of one of those technical teams. At the time he was a young Boeing aeronautical engineer working on a preliminary design for a new generation of jet-powered bombers. After studying the German data on swept wings, Schairer quickly wrote a letter to his colleague, Ben Cohn, at Boeing, alerting the design team to the features of such wings. Schairer asked Cohn to distribute copies of his letter to all major manufacturers so that the entire aeronautical community would understand the benefits of swept wings for high-speed airplanes. In the short run, however, only two companies took advantage of that information: Boeing and North American.

It is unlikely that the swept wing would have revolutionized airplane design so soon after the war if it had not been for Jones. In early 1945, Jones began to look at the mathematical theory of supersonic flows. When Jones applied this theory to delta wings (the name applied to the triangular swept-back wings), he found that he was obtaining equations similar to those he had found for incompressible flow using a crude theory. Searching for an explanation, he recalled that the aerodynamic characteristics of a wing were governed mainly by the component of the freestream velocity perpendicular to the leading edge. The answer suddenly was quite simple. Jones's supersonic findings for the delta wing were the same as his earlier low-speed findings because the leading edge of the delta wing was swept back far enough that the component of the supersonic freestream Mach number that was perpendicular to the leading edge was actually subsonic. The supersonic swept wing, therefore, acted as if it were in a subsonic flow. With that revelation, Jones had independently discovered the high-speed aerodynamic advantage of swept wings, albeit 10 years after Busemann's paper at the Volta Conference.

The first definitive wind tunnel data obtained in America on swept wings in a supersonic flow came from the work of Walter Vincenti, a young aeronautical engineer working at the NACA

Ames Aeronautical Laboratory at Moffett Field in Mountainview, California. The Ames facility was the second aeronautical laboratory built by NACA. In operation by 1941, Ames was earmarked for high-speed aerodynamic research. One of its earliest and most important facilities was the one-by-three-foot supersonic wind tunnel. In the two years following the end of World War II, Vincenti, who was the facility's director, carried out an exhaustive series of tests on swept wings of different shapes, detailing their aerodynamic characteristics and probing the basic physics of their flow fields. Classified as secret until 1949, these data provided the technical basis for the American swept-wing supersonic aircraft for the next decade.

Among scholars, credit for the idea of a swept wing for high-speed flight is shared between Busemann and Jones. Although separated by an interval of 10 years as well as the tight military security of both Germany and the United States, each man independently developed the concept. The full impact of the swept-wing concept on the aeronautical industry emerged after the end of World War II. The almost simultaneous release of similar information from both sides of the ocean promoted confidence in the concept which is the aerodynamic legacy behind all swept-wing aircraft today. The development of the swept-wing concept for a high-speed airframe, in concert with the development of the jet engine, created a revolution in airplane technology. Together these developments represent two of the most important turning points in the era of the jet-propelled airplane.

The jet engine was not, however, invented in America. Credit for that breakthrough goes to Hans von Ohain in Germany and Frank Whittle in England, who each independently invented the successful gas-turbine jet engine for aeronautical applications. After World War II, work at the NACA Lewis Aeronautical Laboratory in Cleveland, Ohio, greatly enhanced American jet engine technology. Detailed research on compressor technology led the Lewis Laboratory to publish a definitive series of reports on gas-turbine compressor design that came to be considered the bible in the field. To this day, extensive jet-engine research continues at the Lewis Laboratory, now renamed the NASA Glenn Research Laboratory in honor of John Glenn.

Development of the Area Rule and the Supercritical Airfoil

Two major developments made efficient transonic flight practical: the area rule and the supercritical airfoil. The transonic region of flight between Mach 0.75 (500 mph) and Mach 1.25 (900 mph) can cause severe instability in aircraft. "In that band," states aerospace historian Richard Hallion, "airplanes encountered compressible flow, shock waves streaming from their wings and bodies, loss of lift and rising drag, dangerous buffeting, and sometimes loss of control and even structural failure."[1] Both the area rule and the supercritical airfoil emerged from the transonic wind-tunnel research directed by Richard Whitcomb, chief of the Transonic Aerodynamics Branch at Langley Memorial Aeronautical Laboratory. The area rule and the supercritical airfoil both sought to reduce drag in the transonic engine. However, they accomplished drag reductions differently.

The area rule states that the cross-sectional area of the body should have a smooth variation with longitudinal distance along the body with no rapid or discontinuous changes in the distribution of cross-sectional areas. For example, a conventional wing-body combination will have a sudden increase in the cross-sectional area where the wing cross section is added to the body cross

[1] Richard P. Hallion, "Richard Whitcomb's Triple Play," *Air Force Magazine*, February 2010, 70, available at http://www.airforce-magazine.com/MagazineArchive/Pages/2010/February%202010/0210whitcomb.aspx (accessed August 26, 2010).

section, "causing a sharp increase in drag." To compensate, Whitcomb decreased the body cross section in the vicinity of the wing, producing a concave taper commonly known as the "wasp waist" or "Coke bottle."[2] By applying the area rule, engineers can considerably reduce the peak transonic drag.

Early analysis had hinted at the theoretical underpinnings of the area rule. However, these ideas were not fully appreciated until Whitcomb conducted a series of wind tunnel tests on various transonic bodies in the slotted-throat wind tunnel which he had developed.[3] This data, and an understanding of the area rule, came just in time to save the air force's new jet-powered interceptor, the Convair F-102, one of the "century series" fighters. The prototype YF-102 had a delta-wing configuration and was powered by the Pratt & Whitney J-57 turbojet, the most powerful engine in the United States at the time.

On October 24, 1953, flight tests of the YF-102 began at Muroc Air Force Base (now Edwards Air Force Base). However, as the flight tests progressed, it became painfully clear that the YF-102 could not fly faster than sound; the rapid rise in drag was simply too great for even the powerful J-57 engine to overcome. After consultation with NACA aerodynamicists and inspection of the area-rule findings that had been obtained in the Langley Aeronautical Laboratory wind tunnel, the Convair engineers modified the airplane to become the YF-102A, with an area-ruled fuselage. Wind-tunnel data on the YF-102A now looked promising.

Encouraged by those wind-tunnel findings, the Convair engineers initiated a flight-test program for the YF-102A. On December 20, 1954, the prototype YF-102A left the ground at Lindbergh Field, San Diego, California, and exceeded the speed of sound while still climbing. The use of the area rule had increased the top speed of the airplane by 25 percent. The Convair eventually became a Cold War mainstay for the air force, and "area ruling became a standard feature of supersonic aircraft." According to Hallion, "Whitcomb had reshaped the airplane. Area Rule was—next to the swept and delta wings themselves—the most significant and most visible manifestation of transonic design."[4]

The supercritical airfoil, also pioneered by Richard Whitcomb, was based on data obtained at both Ames and Langley (especially the eight-foot wind tunnel). An airfoil is the shape of a wing's cross section which defines how much lift the wing generates at various speeds. Compared to a conventional wing, the unique design of the supercritical wing "is shaped flatter on the top and rounder on the bottom with a downward curve at the trailing edge."[5] As a result, the strength of the shock wave is lower, which, in turn, reduces drag. These airfoils are designed to operate far above a wing's critical Mach number. This is the airspeed at which "the air flowing over the wings reaches supersonic speeds though the plane itself is still moving slower than MACH 1, causing a dramatic increase in drag,"[6] hence the term "supercritical" airfoils.

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[2] Donald M. Pattillo, *Pushing the Envelope: The American Aircraft Industry* (Ann Arbor: University of Michigan Press, 2000), 198.

[3] Hallion calls this tunnel "the most significant tunnel advance over the previous 25 years." Hallion, "Richard Whitcomb's Triple Play."

[4] Ibid., commentary 70, 71. Whitcomb was awarded the 1954 Collier Trophy, "the most prestigious of all American aviation accolades" for his development of the area rule.

[5] NASA Dryden Flight Research Center, "F-8 Supercritical Wing," http://www.nasa.gov/centers/dryden/news/FactSheets/FS-044-DFRC.html (accessed August 26, 2010).

[6] Dwayne A. Day, "Supercritical Airfoil," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Evolution_of_Technology/supercritical/Tech12.htm (accessed August 26, 2010).

The navy's Vought F-8A Crusader, with its easily removable wing and Mach 1.7 capability, was chosen as a testbed. Rockwell International's North American Aircraft Division fabricated the wing and delivered it to NASA in December 1969. On May 26, 1971, on Rogers Lake, the F-8 flew at supersonic speeds. Test results showed its transonic efficiency had increased up to 15 percent. Scientists asserted that aircraft with supercritical wings could save fuel, cruise faster, and fly farther than aircraft with conventional wings.[7] NASA introduced the technical community to the supercritical-airfoil data at a special conference in 1972. Since then, the supercritical-airfoil concept has been employed on virtually all new commercial aircraft and some military airplanes. Airlines facing rising fuel costs in the 1970s greatly benefited from this research. Increased speeds plus fuel efficiency raised profit margins for aircraft with supercritical wings by 2.5 percent over passenger transports with conventional wings. In 1974 dollars, "[t]his equated to $78 million per year…for a 280-plane fleet of 200-passenger airliners."[8]

[7] Day, "Supercritical Airfoil"; NASA Dryden Flight Research Center, "F-8 Supercritical Wing."
[8] Day, "Supercritical Airfoil."

COMMERCIAL AVIATION

I have been "whisked, streaked, zipped, flicked, sped, hurtled, flashed and shuttled" across the sky faster than Phaeton's chariot pulled the sun.

—Poet Carl Sandburg, on flying 35,000 feet above his native Illinois in a Boeing 707[9]

In the late 1950s, airliner technology was evolving more rapidly than ever and the introduction of jets further revolutionized the field. Yet, U.S. passenger air carriers were reluctant to support the building of jet airliners in the immediate postwar years. There were two reasons for this. First, jet engine technology required very expensive metal alloy components and used much more fuel than the old piston engines. Second, the initially low takeoff speed required longer runways than those currently in use. As a result, commercial aviation executives initially adopted a wait-and-see approach before embarking on the massive investment required. Ultimately, improved aircraft and engines convinced the executives to invest in jets. Now, swept-wing jet transports, jets for medium- and short-distance travel, and wide-body jets all contributed to an era of mass air transit.

The Swept-Wing Commercial Jet Transport Design: Uniquely American[10]

The Boeing 707 and the DC-8

The design of the Boeing 707, the first commercial jet transport to use swept wings, is one of the most spectacular and important examples of American aeronautical technology in the era of the jet-propelled airplane. This plane pioneered the general configuration of most jet transports to the present day. When Boeing aeronautical engineer George Schairer wrote his American colleagues from Germany in May 1945 about the German work on swept wings, he initiated a radical design change.

British Overseas Aircraft Corporation (BOAC), the national British carrier, became the first carrier to introduce a commercial jet airliner into service.[11] Using the De Havilland 36-seat Comet 1, BOAC inaugurated the service on May 3, 1952. At the time, the top cruising speed of the most well-known piston-engine aircraft, the DC-3, was about 180 miles per hour. With the Comet, passengers could travel comfortably at 480 miles per hour, a revolutionary leap in air travel. Unlike piston-engine planes, the Comet was vibration free and relatively quiet. Unfortunately, the need to repeatedly pressurize and depressurize the aircraft caused metal fatigue, especially around rivet holes. After several accidents, BOAC suspended flights within two years of its introduction. By this time, domestic U.S. companies had begun their own programs to build jet airliners. Several factors, including improved jet engines, had convinced these companies to rethink their initial reluctance to build commercial jet planes.

The dominant features of the 707, the 35-degree swept wing and the jet engines mounted in pods slung under the wing on struts, all began with the revolutionary design of the Boeing B-47

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[9] Carl Solberg, *Conquest of the Skies: A History of Commercial Aviation in America* (Boston: Little, Brown, 1979), 398.

[10] Portions of this section were excerpted or paraphrased from Asif Siddiqi, "The Opening of the Commercial Jet Era," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Commercial_Aviation/Opening_of_Jet_era/Tran6.htm (accessed March 5, 2004).

[11] While BOAC introduced the first commercial jet service, the first jet-propelled aircraft flight took place in Germany on August 27, 1939. Bill Yenne, *Classic American Airliners* (St. Paul: MBI, 2001), 101.

strategic bomber in the late 1940s. The major design changes for the 707 were the low-wing configuration to allow a long body deck for carrying passengers or freight and the use of a tricycle landing gear. The tricycle gear was used simply because airplane pilots were familiar with this type of landing gear. It allowed them to lift the nose at takeoff and depress the nose at landing.

With the success of the Boeing B-47 strategic bomber, and then later with the large B-52, Boeing executives were in an advantageous position to produce the first jet airliner in the United States. However, the decision to proceed with this project was not made easily. Because the airlines were cautious, waiting to see how successful the British-designed jet airliner, the Comet, might be, Boeing felt that initial orders for a new commercial jet transport would be insufficient to cover the development and tooling costs. This hesitation led to the creation of a military version to be used as a jet tanker for in-flight refueling, almost identical to the civil transport design. Business from the air force would thus make up the start-up losses for the development of the civil transport. But the air force dragged its heels on this idea. Nevertheless, on April 22, 1952, Boeing authorized the building of a prototype jet airliner, changing forever the fortune and future destiny of the Boeing Company. After producing mainly military airplanes for most of its existence, Boeing was now poised to become the world's leading manufacturer of civil jet transports in the last half of the twentieth century.

Initially, the prototype jet transport, with an estimated cost of $16 million, was to be privately financed. However, Boeing decided to use some of its independent research and development funds, which came from pro-rated allotments taken from military contracts. These independent funds enabled the government to provide discretionary funding to companies for research and advanced development. By using these funds, Boeing kept their costs to $3 million with the government indirectly paying the remaining $13 million. Boeing labeled the prototype with a company internal designation of 367-80, but the airplane quickly became known as the "Dash-80."

The first flight of the Dash-80 took place on July 15, 1954, and the first production 707s were delivered to Pan American Airlines in September 1958. On October 26, Pan American flight 114 departed Idlewild Airport, New York, at 7:02 p.m. and landed at Paris's LeBourget about nine hours later, with an intermediate stop at Gander, Newfoundland, for refueling. This was the first jet service offered by a U.S. flag carrier.[12]

Of all the airlines in the United States, Pan American was undoubtedly the pioneer in embracing jet aviation. Early on, Juan Trippe had expressed a keen interest in operating a passenger jet service capable of flying nonstop across the North Atlantic.[13] After seeing the bright promise of the British Comet fade, Trippe played off two of the biggest domestic airplane builders, Boeing and Douglas. Both companies were eager to address Pan American's needs, offering the Boeing 707 and the DC-8.[14]

[12] The early model 707 did not have sufficient range, when fully loaded, to make the trip from New York to Paris nonstop.

[13] According to noted historian R. E. G. Davies, the three main reasons for the timing of the jet age were Pan American, the availability of wartime aeronautical talent for civil projects, and the courage of manufacturers to invest millions into colossal risks. R. E. G. Davies, *Airlines of the United States since 1914*, rev. ed. (Washington, DC: Smithsonian Institution Press, 1982), 510.

[14] The 707 evolved from the prototype Model 367-80, commonly known as the Dash 80, that first flew in July 1954. A variation was marketed to the U.S. Air Force as an in-flight refueling aircraft. Orders began to flood in for the "four-engined jet with a range and payload that would transform long-distance travel." R. G. Grant, *Flight: 100*

In October 1955, Trippe signed contracts with both companies for 20 of the 707s, and 25 of the DC-8s based on the facts that the DC-8 could fly the Atlantic nonstop, but the 707, which could fly the Atlantic nonstop only under the right winds, was first. At a cost of $269 million, the purchase was the largest ever in aviation industry. With this order, "Trippe took the world's airlines into the jet age." He announced his purchase at a party in his Manhattan apartment. His guests were members of an executive committee attending an industry meeting at the Waldorf-Astoria. Trippe's biographer, Robert Daley, describes the moment:

> [Trippe] moved through the crowded room shaking hands, flashing his most ingratiating smile, mentioning in the most casual kind of way that he had just bought forty-five jet airliners, and that the news was even now being released to the papers. As his guests grasped the import of this, whole corners of the room fell abruptly silent.[15]

Exactly two years later, Boeing rolled out the first operational 707 (the 707-120), and on October 26, 1958, amid much fanfare, Pan American inaugurated its New York–London route. The flight, historian Roger Bilstein states, "ushered in new standards for airline travel and helped the United States dominate the world market for jet transports."[16] The 707 carried twice the passengers the new model Comets could hold and much more than the latest propliners. At 600 miles per hour, it flew far faster than a propliner or turboprop. "At a stroke, long-distance journey times were almost halved."[17]

At first, BOAC competed with Pan American. The British airline had rushed ahead and inaugurated its own transatlantic service on October 4, 1958, just three weeks ahead of Pan American. BOAC used the new De Havilland Comet 4, which incorporated improvements intended to remedy the problems with the older Comet 1. Although BOAC fared quite well, its success paled in comparison to that of Pan American. With its rapidly expanding use of the Boeing 707, especially on the transatlantic route, Pan American began a period of almost unchallenged dominance in the international airline industry. As the first airline to recognize the importance passengers placed on long nonstop flights, Pan Am negotiated with Boeing for a version of the 707 (the 707-320) that could fly for a longer time without refueling. On August 26, 1959, the airline introduced true intercontinental service with nonstop London to New York flights. Pan Am had defined the characteristics of a new class of jets that the industry would produce.

Although many other airlines were the first to offer regular services on various international routes, Pan American Airways set the standards for service in the new jet era. The airline's pioneering partnership with Boeing, its ambitious routes—such as its round-the-world jet service inaugurated in October 1959—its flashy advertising campaigns, and its reputation for good service, all made the company a leader and a trendsetter.

Beyond international routes, the Boeing 707 initiated competition among coast-to-coast routes. National Airlines offered the first 707 domestic service on December 10, 1958. American

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Years of Aviation (New York: DK, 2002), 382-83.

[15] T. A. Heppenheimer, *Turbulent Skies: The History of Commercial Aviation* (New York: John Wiley & Sons, 1995), 164-65.

[16] Roger E. Bilstein, *Flight in America: From the Wrights to the Astronauts*, 3rd ed. (Baltimore: Johns Hopkins University Press, 2001), 229.

[17] Grant, *Flight,* 382, 383.

Airlines followed on January 25, 1959, with a flight from New York to Los Angeles. With this coast-to-coast service, American struck a competitive coup; as the two other major domestic airlines, TWA and United, had not anticipated using jets for domestic service. From its corporate headquarters in Kansas City [TWA Corporate Headquarters' Building, NR, 2002], TWA quickly scrambled to catch up. Using a single Boeing 707, it joined the coast-to-coast flight market in March 1959. The last-minute move helped keep TWA afloat through a difficult period of overall financial loss.

Not all airlines pinned their hopes on the Boeing 707. Douglas had unparalleled experience in building the best passenger airliners in the world and, in June 1955, the company announced it would build a turbojet powered airliner, the DC-8. The new aircraft was half again as fast as the DC-7 and could carry almost twice the passengers.[18] United Airlines and Delta both began flying the DC-8 in September 1959, and Eastern Airlines joined them in domestic jet services in January 1960.

Jets revolutionized air travel throughout the world. Thirty-two million people flew on domestic flights alone in 1954. Five years later, that number increased to 55 million. And the airlines continued to grow. According to a 1956 *Fortune* magazine survey "any one of the Big Four domestic airlines is bigger than the entire domestic industry was only a decade ago."[19] Passengers experienced more comfort, less noise, and most important, less travel time. Once again, as with the introduction of piston engines into civil aviation in the 1920s, a technological revolution in aviation reduced the size of the world.

Medium- and Short-Distance Commercial Jet Travel[20]

There was still an air of glamour surrounding long-distance flight, but it was far from the propliner era of well-groomed sophisticates sipping cocktails in an airborne bar. Jet travel was slick, brash, and totally modern.

–R. G. Grant[21]

The Boeing 727 & the DC-9

In the early 1960s, the public expected jet service for flights over long and even medium distances, such as between New York and Chicago. Now the industry needed a jet equivalent to the revolutionary 1930s DC-3 to bring safe and reliable air service to small and medium-size cities, connecting them to each other and beyond.[22] Airline operators faced the challenge of transferring the appeal of the new jets—their speed, comfort, and reliability—to much shorter routes.

Because of their high fuel consumption, the first jets were profitable only along longer routes at high constant cruising speeds and with high annual use—neither of which could be achieved on short routes. In the early 1960s, advances in jet engine technology, especially the introduction of the fanjet engine, produced new levels of reliability and efficiency along with lower noise levels,

[18] Yenne, *Classic American Airliners*, 123.
[19] Heppenheimer, *Turbulent Skies*, 170.
[20] Portions of this section are excerpted or paraphrased from Asif Siddiqi, "The Era of Commercial Jets," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Commercial_Aviation/Jet_Era/Tran7.htm (accessed March 5, 2004).
[21] Grant, *Flight*, 386.
[22] Yenne, *Classic American Airliners*, 149.

making jets attractive for short routes. The innovator in this area was not an American aircraft, but a French one, known as the Caravelle, built by the Sud-Est Aviation (later Sud-Aviation) company. Air France had flown this sleek twin-engine aircraft since 1959, and, in July 1961, United Airlines began using the Caravelle on its New York–Chicago route.

Taking a cue from the design of the Caravelle, Boeing built the 727, a larger and faster jet with three engines, perfect for both medium- and short-distance routes. Its sophisticated wing flaps and slats allowed the plane to land and take off from shorter runways at smaller airports, permitting many cities to add jet service for the first time. Eastern Air Lines began using the Boeing 727 on its Philadelphia—Washington—Miami route on February 1, 1964. United followed five days later on its San Francisco—Denver route, followed within four months by American and Trans World Airlines (TWA). It became the first plane to pass the 1,000 sales mark, and, by the mid-1970s, as many as 60 airlines all over the world were flying the 727. When production ended in 1984, the aircraft had become the "world's best-selling jet transport." Douglas offered its own DC-9 to compete with the 727 on its shorter routes, and after entering service in December 1965 with Delta Air Lines, the DC-9 also sold in large numbers around the world.[23]

The Wide-Body Jets: Bigger May Not be Better

The Boeing 747 and the DC-10

Another major airliner advance was the introduction of wide-body jets. Here, Pan American played a key role in shaping the economics and eventual design of a new generation of jets. Pan American's primary focus had always been to lower its operating costs by having higher block speeds (average time for gate-to-gate service), higher aircraft use, and/or higher load capacities. Having maximized all of these factors, Juan Trippe, pursued the only remaining option: a massive airplane capable of carrying hundreds of passengers that would be an ocean liner for the skies. By defining requirements for size and passenger capacity, Trippe was instrumental in determining the eventual shape of Boeing's new aircraft—the 747—which could carry as many as 490 passengers.[24]

Trippe ordered 23 747s for Pan American in April 1966. To make this huge airliner, Boeing constructed an entirely new factory. The building, larger in volume than any other building in the world, was located in Everett, Washington. On January 22, 1970, Pan Am's first Boeing 747 took off from New York's John F. Kennedy Airport and headed out over the Atlantic. Other airlines followed Pan American's lead. TWA inaugurated Boeing 747 service on its New York–Los Angeles route in February 1970, followed the next month by American Airlines on the same route. Airlines such as Continental, Northwest, United, Delta, National, Eastern, and Braniff all followed with their own 747 services within the year. In an assessment of the Boeing's 747's introduction in 1970, history writer R. G. Grant notes that the airliner "transformed the scale of long-distance passenger flight…ushered in the age of mass air travel.…[and] was the last product of the visionary era of commercial aviation."[25] The early momentum from the fascination with

[23] Grant, *Flight,* 388, 389 on number sold; Bilstein, e-mail message to author, November 2004. The 727 was the first jetliner ever certified to operate from a gravel runway. Yenne, *Classic American Airliners,* 149.
[24] Boeing had concentrated on the design of the 707 after losing a contract to Lockheed for the C-5 military cargo in September 1965. David Donald, ed., *The Complete Encyclopedia of World Aircraft* (New York: Barnes & Noble Books, 1997), 171.
[25] Grant, *Flight,* 377, 394, 400; quote, 377, 394.

wide-body jets did, however, produce two other wide-body aircraft, the Lockheed L-1011 TriStar and the Douglas DC-10, each capable of carrying about 300 passengers. American Airlines used the DC-10 for the first time in August 1971. Eastern Airlines became the first to use the TriStar in April 1972.

By the mid-1970s, the major airlines had a slightly more cautious approach to the "big-is-better" approach. Despite the savings from wide-bodied jets, airline fares did not drop significantly, the new planes were not faster than earlier jet aircraft, and not all passengers liked sitting in a cabin with ten seats abreast and two aisles. Ironically, the introduction and use of the wide-body jets may have contributed to an economic downturn for airlines in general. The early 1970s was a very tenuous time for many airlines—traffic growth stagnated even as airlines introduced additional passenger capacity. After several airlines appealed to the CAB, the agency granted a general increase in airfares (about 6 percent) as a safety net for the airlines. Unfortunately, the higher fares decreased passenger traffic even more, resulting in a "bottoming out" in 1971.

Internationally, airlines such as Pan American and TWA also felt the pinch, as low-fare charter services stole their business, especially on the transatlantic routes. After tense series discussions with other International Air Transport Association (IATA) carriers in 1971, all the major transatlantic carriers agreed to lower transatlantic fares. In 1972, these fares were the lowest in history, bringing intercontinental travel within the reach of a whole new economic group.[26] Over one million passengers had flown to Europe in 1958, but by 1968, transatlantic passenger service increased to six million per year.

During the 1970s, the annual rate of total U.S. air traffic growth slowed, but there was never any real decline in the number of flights. In fact, the number of passengers grew significantly despite fare increases, evidence of the public's increasing reliance on air travel as a routine activity. "As such," states Grant: "it [jet flight] inevitably lost its connotations of glamour, romance, or excitement.…While airliners carried on changing the world, after 1970 the world of airliners changed comparatively little. The last 30 years of the twentieth century brought no further revolution in speed or size."[27] Originally the public had viewed the aeroplane as "the subject of awe," and later a variety of aircraft provided the public with an "intriguing period." But by 1972, "the word jet has become synonymous with commercial aeroplane and few know, or care, which type is used by the airline."[28]

[26] Davies, *Airlines of the United States*, 577. IATA, founded in 1945, was "a voluntary organization whose main purpose would be to prevent airlines from practicing unethical methods in rates and scheduling." Davies, *Airlines of the United States*, 369.
[27] Grant, *Flight*, 397, 398.
[28] Davies, *Airlines of the United States*, 530.

AIRPORTS

The first siren whoosh of the commercial jetliner in the late '50s… set off an earthbound revolution that transformed the whole façade and function of the jet-age airport.

--Martin Greif[29]

Jets required enormous runways for take-offs and landings, and added hundreds of passengers and their luggage to airports. The introduction of jet aircraft to commercial aviation prompted the redevelopment of airports or the building of new ones. In addition, the introduction of jet aircraft prompted a debate over regional airports and a new option for airport management: multi-jurisdictional airports.

Airport Architecture as Symbol

Almost as soon as it completed construction on the Washington National Airport, the Civil Aeronautics Administration (CAA) realized the nation's capital would need either an expanded facility or a second airport to serve its transportation needs in the future. Debates over expanding National or building a new airport emerged at the end of World War II and continued into the 1950s. Finally, in 1958, President Dwight D. Eisenhower intervened, selecting Chantilly, Virginia, as the site of a new airport to serve the Washington area. A design team, which included architects Eero Saarinen and Associates, began work in April 1958. The architects presented a design that included as a key feature "mobile lounges" to move passengers from the terminal to their planes. Built by the Chrysler Corporation, the lounges allowed "convenient loading and unloading while protecting passengers from inclement weather." The lounges, in turn, allowed the architects to design "a grand terminal with minimal walking space." Although the airlines resisted the mobile lounge idea, the CAA accepted the recommendation and the "airport opened in 1962 to wide acclaim."[30]

Washington Dulles International Airport is also significant as the first airport designed for the new commercial jet aircraft introduced in 1958. The airport covered 10,000 acres and originally had two parallel runways 11,500 feet long and a 10,000-foot crosswind runway. The main terminal was built between the parallel runways, "a configuration that would become popular at successive jetports." Also designed for expansion, Dulles had four remote terminals added between the runways. The mobile lounges shuttled passengers between the main and remote terminals. At the remote terminals, passengers board their planes via jetways.[31] The mobile lounges fell out of favor as airport expansions and new security measures made mobile lounge waiting areas crowded. In January 2010, the Metropolitan Washington Airports Authority announced the arrival at Dulles of an underground airport train system. The AeroTrain quickly moves passengers from the main terminal to the midfield concourses.[32]

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[29] Martin Greif, *The Airport Book: From Landing Field to Modern Terminal* (New York: Mayflower, 1979), 142.
[30] Zukowsky, *Building for Air Travel*, 93.
[31] Szurvoy, *American Airport*, 126-28.
[32] Metropolitan Washington Airports Authority, "AeroTrain Has Arrived!" http://www.metwashairports.com/file/pr2010_01_26.pdf (accessed September 7, 2010).

Trans World Airlines Flight Center (TWA Terminal 6), Jamaica, New York, 2005. Source: National Park Service

In May 1962, another terminal designed by Eero Saarinen opened to wide acclaim: the Trans World Airlines Flight Center [National Register, 2005] at John F. Kennedy International Airport, New York City. The terminal is significant for both its sweeping design and technological innovations designed to meet the passenger load created by the 400-seat Boeing 747 jumbo jet. The terminal's "soaring central structure suggests the flight of a great bird…a design calculated to stir in people the excitement and drama of air travel."[33] Saarinen and Associates planned the center as a satellite terminal, "with aircraft clustered around a separate compact building rather than a long finger with airplanes parked in a line."[34] Its satellite passenger loading areas influenced future airport terminal designs.[35]

Multi-Jurisdictional Airports

Public authorities represented one new option for airport management. However, the multi-jurisdictional airport was more common. As early as 1942, *American City* reported that six states had recently passed laws allowing two or more cities, or cities and counties, to jointly own and operate airports. In 1944, Charles Rhyne, an airport law expert, presented a more thorough study of the issue that reported that 32 states had such legislation and that joint airports were in operation in 20 states.[36] Though many of these joint ventures involved small cities, one of the most prominent involved the cities of Dallas and Forth Worth, Texas. The construction of this airport was one of the few new major airports in the postwar period although the airport did not open until 1974.

The idea of a joint Dallas–Fort Worth airport had originated in the late 1930s. Following the passage of the Air Commerce Act, federal officials strongly encouraged the two cities to cooperate and build an airport to replace both Dallas's Love Field and Fort Worth's Meacham Field. Local leaders rejected the idea. They viewed Dallas and Fort Worth as separate metropolitan regions and, as such, each needed its own airport. Although a CAA plan to develop an airport in Arlington, Texas, a small town between the two larger cities, led to a temporary agreement to cooperate, Dallas withdrew from the agreement in the end. The CAA, however, carried out a version of its original plan, developing a new airfield for use by the military in Arlington.[37]

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[33] Grief, *Airport Book*, 150.
[34] Zukowsky, *Building for Air Travel*, 137.
[35] Kathy Howe, "Trans World Airlines Flight Center," National Register of Historic Places Registration Form (Washington, DC: U.S. Department of the Interior, National Park Service, 2005), Section 8, Page 1.
[36] "Legislation Gave Cities Broader Airport Control," *American City* 57 (April 1942): 11; Charles Rhyne, *Airports and the Courts* (Washington, DC: National Institute of Municipal Law Officers, 1944), 39-40.
[37] Robert B. Fairbanks, "Responding to the Airplane: Urban Rivalry, Metropolitan Regionalism, and Airport Development in Dallas, 1927-1965," in *Technical Knowledge in American Culture: Science, Technology, and Medicine since the Early 1800s*, ed. Hamilton Cravens, Alan I. Marcus, and David M. Katzman (Tuscaloosa:

After World War II and the passage of the Federal Airport Act, the CAA renewed its efforts to promote a joint Dallas–Fort Worth Airport. Airline officials also pressed for a new regional airport. Dallas leaders continued to resist, but Fort Worth accepted CAA funding to transform the now-abandoned army airfield near Arlington into its new municipal airport, Carter Field. In the meantime, a Dallas planning report provided evidence to support the continued use of Love Field. It emphasized Love Field's economic role in creating jobs and helping to sustain Dallas's position as a center of commerce. Civic leaders in Dallas responded to the report with a vigorous campaign to improve and expand Love Field, even in the absence of federal funding. In 1953, Dallas voters approved a $5-million bond issue which, along with $5 million in revenue bonds, financed major work at the field.[38]

Pressure from the CAA diminished during the early and mid-1950s, but the arrival of jet airliners in the late 1950s, along with its noise issues and demand for even longer runways, brought a renewal of the regional airport debate. The FAA,[39] successor to the CAA, deemed Love Field inadequate for the city's aviation needs and stated it would provide no additional funds for expansion or other improvements. Instead, the FAA urged Dallas and Fort Worth to work together on a new regional airport, suggesting that they use Fort Worth's new municipal airport. In September 1964, following lengthy debates, the FAA declared that a single regional airport would serve both cities. City authorities had 180 days to decide on a location. After an extension of the deadline, the two cities agreed to build a new regional airport north of the Carter Field site.[40] The first commercial flight landed at the new Dallas–-Fort Worth International Airport in January 1974.

The introduction of jet airliners and the need for federal funds clearly prompted the final agreement between Dallas and Fort Worth. A changing vision of the metropolitan area may have also played a part. In the 1940s and 1950s, both cities saw themselves as separate and competing metropolitan regions. By the 1960s, however, decentralization had produced a new combined metropolitan region, one linked by highways and communication technologies that could be "anchored not by a city but by an airport."[41] When Dallas was willing to self-finance its airport and make improvements that could meet federal standards, federal officials had limited leverage. However, once Love Field reached its limits in terms of expansion and fell short of federal standards, federal officials could threaten the city with the loss of airline service. The need to maintain service, along with promised federal funds, shaped the decision of both Dallas and Fort Worth civic leaders to build a single regional airport. Clearly, the federal government's ability to influence and determine local airport decisions had increased.

University of Alabama Press, 1996), 172-76.

[38] Ibid., 179-84.

[39] The Federal Aviation Act of 1958, created the Federal Aviation Agency, an independent body. The new FAA took on the responsibilities of the old CAA, which had been part of the Department of Commerce. The administrator of the FAA reported directly to the president. In 1966, Congress created the Department of Transportation and the FAA became an organization under the new department. As part of the reorganization, the name changed to the Federal Aviation Administration and the administrator was to report to the secretary of commerce.

[40] Fairbanks, "Responding to the Airplane," 183-88.

[41] Ibid., 187-88.

DEREGULATING THE AIRWAYS

The Airline Deregulation Act of 1978

During the 1970s the nation's airlines had become a form of mass transit. The "Big Four" airlines Brown had created through the airmail contracts in the 1930s—United, Eastern, American, and TWA—remained in existence 50 years later. In addition, Pan American, which had received international monopoly status, was still the leader in American international airlines.[42] For 40 years between 1938 and 1978, the Civil Aeronautics Board regulated airlines, controlling their schedules, the fares they could charge, and the routes they could fly. Congress deregulated the industry in 1978 over concerns "that these practices caused economic inefficiencies and inhibited the growth of domestic air transportation."[43] The ensuing free competition ushered in a new era in passenger air travel. For the first time in 40 years, airlines could enter the market or expand their routes as they saw fit. They also had freedom to set their fares. In 1984, the CAB was finally abolished since its primary duty of regulating the airline industry was no longer necessary. Freed from the rules of the CAB, regional and major airlines inaugurated new routes in droves, competing in a no-holds-barred competition for passenger business. As a result, fares dropped dramatically and total operating revenues for the major national and international airlines rose to a high in 1979.[44]

Deregulation impacted the airline industry both positively and negatively. On the positive side, travelers saved $100 billion in airfares in the first ten years and they booked flights on shorter routes offered by smaller airlines that were not profitable for the large carriers. On the negative side, passengers faced inconvenient schedules and reduced airline service. In the early 1980s the airlines suffered in the wake of increased fuel costs and an economic recession. Passenger traffic fell off and the airlines recorded net operating losses. By 1989 Eastern went bankrupt; the bankruptcies of Pan American, Braniff and TWA followed. New start-ups such as People Express, which itself failed a few years later, and Southwest Airlines replaced the old airlines. Of the six major airlines that operated in 1978, only United, American, TWA, and Delta remained in 2005. Writing in 1995, T. A. Heppenheimer concluded, "…the industry's continuing large losses show that the consequences of deregulation still have not run their course. Fifteen years into this new era, the nation's airlines remain caught in a shakeout, a shakeout born of those laws, and one from which there has been, and continues to be, no exit."[45]

The impact of the Airline Deregulation Act of 1978 remains a subject of debate, with much of the attention focused on the changes in the airline industry. Limited attention has been given to the act's impact on airports. Nonetheless, deregulation has had far-reaching consequences for airport operations. First, deregulation resulted in the broader adoption of the hub-and-spoke system. Before deregulation, most airports—even major airports—were designed to accommodate travelers moving from point to point (or direct route). The hub-and-spoke system, with its increase in the number of necessary connecting flights from a central (or transfer) airport

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[42] Heppenheimer, *Turbulent Skies*, 314-15.

[43] United States General Accounting Office, "Airline Deregulation: Changes in Airfares, Service Quality, and Barriers to Entry, March 1999," http://www.gao.gov/cgi-bin/getrpt?GAO/RCED-99-92 (accessed August 16, 2005).

[44] Asif Siddiqi, "Deregulation and Its Consequences," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Commercial_Aviation/Dereg/Tran8.htm (accessed March 5, 2004).

[45] Ibid., quotes, T. A. Heppenheimer, "Air Transport—Commercial Aviation—An Overview," U.S. Centennial of Flight Commission, http://www.centennialofflight.gov/essay/Commercial_Aviation/Tran-OV.htm (accessed March 5, 2004); Heppenheimer, *Turbulent Skies*, 343. In December 1991, TWA merged with American.

and out along spokes, led to new forms of airport design. Secondly, the combination of the turbulence caused by deregulation and the hub-and-spoke system worked to create a riskier financial environment, especially for the emerging major hub airports.[46]

Though the adoption of the hub-and-spoke system is associated with the advent of deregulation, it predates the 1970s. Both Delta and Eastern Airlines, for example, used the Atlanta airport as a hub as early as the 1950s. Yet, the city built its first postwar terminal, completed in 1961, to accommodate point-to-point or origin-and-destination (O & D) traffic, as it came to be known. When increased air traffic during the 1960s necessitated the construction of another, larger terminal, Atlanta's airport planners initially continued to design for O & D traffic, rather than transfer passengers. However, Betsy Braden and Paul Hagan have pointed out that a variety of circumstances—escalating costs, debates over a reliever airport, and an economic downturn in the early 1970s—delayed construction of the new terminal and these delays worked to the design team's favor.[47]

Though the original design followed established practices, by 1973 the design team had a conceptual breakthrough. The proposed layout included one terminal with two functionally distinct sections. The "airside" section included the gates while the "landside" section handled ticketing and baggage claim. Access roads and automobile parking areas were located away from the airside section, closer to the landside section. A "people mover" shuttled passengers from the landside section to the airside section with its six concourses. Though the design witnessed refinements over the years (including a reduction of the number of concourses from six to four), the basic idea remained the same. This new design, acknowledging the growth of hub-and-spoke passenger traffic through the airport, made Atlanta Hartsfield International Airport (now Atlanta Hartsfield-Jackson International Airport) the first airport to begin "to deal with the particular requirements of a transfer airport" when it opened in September 1980.[48]

Deregulation and the shift to the hub-and-spoke system that it accelerated also made the financial situation at airports more risky. Under regulation, once the CAB approved airline service to an airport that service generally remained in place. Permission to inaugurate new service required a tremendous amount of time and paperwork. Similarly, permission to withdraw service also required great effort. Consequently, airlines found it advantageous to negotiate stable, long-term leases with the airports they served. Under deregulation, it became far easier for airlines to initiate service and, moreover, to withdraw service from a particular airport. This more flexible and fluid environment meant that airlines negotiated for shorter-term agreements with airports. Long-term airport planning based on lease revenues was now more difficult and risky. Additionally, because hub-and-spoke airports tended to be dominated by one or two carriers, investors saw increased financial risk as the health of the airport now depended on the health of the carrier. A poor performance by the airport's dominant carrier could adversely affect the bond rating of the airport. As the dominate carrier or carriers have worked to monopolize most of the available gates and concourse space, competition has been curtailed, threatening the potential

[46] Janet R. Daly Bednarek and Michael H. Bednarek, *Cities Take Flight: A Centennial History of the American Municipal Airport*, Essays in Public Works History no. 23 (Kansas City: American Public Works Association, June 2004), 63-69.
[47] Betsy Braden and Paul Hagan, *A Dream Takes Flight: Hartsfield Atlanta International Airport and Aviation in Atlanta* (Athens: University of Georgia Press, 1989), 125-26, 148-77, 182.
[48] Ibid., 183-86, 216.

growth of the airport. Finally, because airlines help finance airport improvements, dominant carriers can stymie local expansion efforts by refusing to participate.[49]

Through regulation and deregulation, the introduction of jet airliners, battles over noise, the vast expansion of passenger air traffic, and myriad new technologies that support the air traffic system in the United States, major airports have become far more complex and expensive than the first enthusiastic generation of airport boosters could have imagined. Particularly due to the expansion of air passenger traffic since World War II, airports throughout the United States, and throughout the world, have struggled to keep up with the growth. As a result, it may seem to observers that the nation's airports are in a perpetual state of change and renewal as construction projects, large and small, seem a constant.

[49] Ann Graham, "Airports in the United States," in *The Airport Business*, ed. Rigas Doganis (New York: Routledge, 1992), 200-03.

NATIONAL HISTORIC LANDMARKS REGISTRATION GUIDELINES

National Historic Landmarks (NHLs) designated under the *American Aviation Heritage* theme study must be acknowledged as being among the nation's most significant properties associated with aviation history. Nationally significant associations and a high degree of integrity are the thresholds for designation. NHL criteria (*Code of Federal Regulations*, Title 36, Part 65.4 [a and b]) are used to assess whether properties are nationally significant for their association with important events or persons.

Criteria of National Significance

According to the criteria, the quality of national significance can be ascribed to districts, sites, buildings, structures, and objects that:

- Possess exceptional value or quality in illustrating or interpreting the heritage of the United States in history, architecture, archeology, engineering and culture, and;

- Possess a high degree of integrity of location, design, setting, materials, workmanship, feeling and association, and:

Criterion 1: Are associated with events that have made a significant contribution to, and are identified with, or that outstandingly represent, the broad national patterns of United States history and from which an understanding and appreciation of those patterns may be gained; or

Criterion 2: Are associated importantly with the lives of persons nationally significant in the history of the United States; or

Criterion 3: Represent some great idea or ideal of the American people; or

Criterion 4: Embody the distinguishing characteristics or an architectural type specimen exceptionally valuable for the study of a period, style or method of construction, or that represent a significant, distinctive and exceptional entity whose components may lack individual distinction; or

Criterion 5: Are composed of integral parts of the environment not sufficiently significant by reason of historical association or artistic merit to warrant individual recognition but collectively compose an entity of exceptional historical or artistic significance, or outstandingly commemorate or illustrate a way of life or culture; or

Criterion 6: Have yielded or may be likely to yield information of major scientific importance by revealing new cultures, or by shedding light upon periods of occupation over large areas of the United States. Such sites are those which have yielded, or which may reasonably be expected to yield, data affecting theories, concepts and ideas to a major degree.

A property must have a direct and meaningful documented association with an event or individual and must be evaluated against comparable properties before its eligibility for landmark designation can be confirmed. When evaluating properties for national significance,

consideration must be given to determining an event's impact or influence. While many individuals, institutions, and organizations played important roles in the history of aviation at the local, state, and regional level, a comparatively few possess exceptional value or quality in illustrating or interpreting American aviation history. An argument, based on a scholarly assessment, must effectively show that the significance ascribed to a property was not only national, but also exceptional within its historic context.

The following text applies the NHL criteria to aviation-related properties.

Criterion 1

Criterion 1 recognizes properties important for their historic association with either a specific event marking an important moment in American history, or with a pattern of events that made a significant contribution to the development of the United States. Properties evaluated under Criterion 1 will be significant within at least one of the five chronological eras developed in this study's historic contexts: 1) The Pioneering Years, 1861-1909, 2) The Early Years & World War I, 1909-1918, 3) Between the Wars, 1918-1939, 4) World War II, 1939-1945, and 5) Post War & Cold War Aviation, 1945-1978. In order to prove significance under this criterion, a property must outstandingly represent a new era or symbolize a pivotal event in American aviation. A significant national contribution to American aviation will be one associated with a seminal development that proved highly influential in an original way; constituting or providing a basis for further development. Such contributions often significantly altered how the federal government regulated aviation, revolutionized air travel, or realized military doctrine.

Examples of places associated with aviation history that may be eligible for consideration under Criterion 1 might include:

- A pioneering a*ircraft* that ushered in the aviation age or revolutionized air travel;
- *Production plants* that inaugurated the aviation industry or made outstanding contributions to the advancement of aeronautical technology in America;
- An *air terminal* that importantly depicts the arrival of the 1930s modern airliner or the postwar jet age;
- An *aid to navigation* deemed crucial to the early growth of civil aviation and the development of the lighted airway;
- A *military base or air station* recognized for its exceptional contributions to national defense in tactical strategies and weapons testing, or considered critical to the formation of war policy and doctrine in World War II;
- An *administrative or educational facility* highly distinguished for its outstanding contribution to advancing American aeronautical technology;
- An *aviation wreck* site associated with vastly modernizing the country's airways;
- *Development facilities* where test equipment produced visionary aircraft that made the United States an undisputed leader in applied aerodynamics, or introduced a new era in air travel or air power.

Criterion 2

Properties designated as NHLs under this criterion must be associated with individuals who played critical roles within the *American Aviation Heritage* context. The individual must have made nationally significant contributions that can be specifically documented and that are

directly associated with both the aviation context and the property being considered. To determine a definitive national role, it will be necessary to compare the individual's contributions with the contributions of others in the same field.

Individuals whose associated places may be considered under NHL Criterion 2 might include:

- *Pioneering aviators* considered exceptionally important for advancing aeronautical theory;
- *Airline executives* whose outstanding contributions placed the airline industry in a new era;
- *Engineers or scientists* who pioneered basic tenets and techniques of aeronautical engineering that maximized the performance of revolutionary aircraft;
- *Army, naval, or air force leaders* who significantly transformed military aviation programs.

Criterion 3

Properties are likely to be eligible under NHL Criterion 3 only in those rare instances when they are strongly associated with ideas and ideals of the highest order in the history of aviation. No historic aviation property has been evaluated under Criterion 3.

Criterion 4

Criterion 4 recognizes properties significant for their physical design or construction, including such elements as architecture, landscape architecture, and engineering. In order to prove significance under this criterion, a property must be substantiated as an exceptionally important work of design.

Places associated with aviation history that may be eligible for consideration under Criterion 4 might include:

- *Aircraft* that either revolutionized the air transportation industry, made a significant contribution to aircraft technology associated with a new era in aviation, or proved crucial to implementing war tactics and strategy;
- An *air terminal* that embodies state of the art design in airfield or terminal/hangar development, served as a model/precursor that represents a new generation of airports, or introduced innovations enormously influential on airport design throughout the country;
- A *military base* or *air station* considered exemplary in airfield planning and design;
- A *development facility* where equipment realized major aerodynamic breakthroughs in the eras of propeller driven or jet-propelled aircraft;
- An *aid to navigation* representing a rare example of a type of beacon on the pioneering 1920s transcontinental air route.

Criterion 5

Criterion 5 recognizes districts that collectively possess exceptional *historic* importance and which may also be considered for designation under NHL Criterion 1. *Architecturally* significant districts are more likely to be designated under NHL Criterion 4. Military airfields and stations that possess exceptional historic importance may be eligible for designation under Criterion 5.

Criterion 6

Criterion 6 recognizes archeological properties. In order to prove significance under this criterion, a property must be likely to yield nationally significant information that has or will make a major contribution to history such as the physical characteristics of an aircraft that provides information about the craft's construction, use or operations. Aviation wrecks and aviation facilities that contain archeological deposits and/or features (such as ruins) that date to the period of significance may also qualify for NHL designation under Criterion 6. For instance, a rare aircraft type that can be documented through archeological investigation may be eligible under this criterion. Sites of aircraft wrecks may also provide nationally significant information about why the craft crashed and could potentially include human remains. Archeological deposits at aviation facilities may yield nationally significant information such as the location of buildings, the evolution of the layout of a particular facility, and information about the work and lives of people living and/or working at a facility. Applicability of Criterion 6 and national significance will depend upon the research design and the questions asked.

National Historic Landmark Exceptions

Certain kinds of property are not usually considered for NHL designation including religious properties, moved properties, birthplaces and graves, cemeteries, reconstructed properties, commemorative properties and properties achieving significance within the past fifty years. These properties can be eligible for listing however, if they meet special requirements called NHL Exceptions. The following four exceptions arose during the course of this study:

Exception 1. A religious property may be eligible for consideration if it derives its primary national significance from its architectural or artistic distinction or historical importance. An example of a religious property is the distinctive Cadet Chapel, a contributing resource of the United States Air Force Academy, Cadet Area, an NHL in Colorado Springs, Texas. The chapel derives its primary national significance from its architectural distinction as an exceptional example of postwar modern movement architecture.

Exception 2. A building or structure that has been moved from its original location may qualify for designation if its primary national significance is its architectural merit or it is associated with persons or events of transcendent importance. Moving a property usually destroys the relationships between the property and its surroundings, historic events, and persons. An example of a property not considered eligible for NHL designation is the Wright family home moved by Henry Ford to Greenfield Village in 1937 as part of Ford's vision of small-town America. To be eligible under Exception 2, aircraft, which are designed to move, must be located in a historically appropriate setting such as an airport or military base.

Exception 7. A property that is primarily commemorative in intent may be eligible for NHL consideration if design, age, tradition, or symbolic value has invested it with its own national historical significance. The Wright Brothers National Memorial, designated a historic site by Congress and listed on the National Register, commemorates the Wright brothers' conquest of air. The shaft's design is also significant for its outspread wings in bas-relief on the sides of the obelisk, giving the impression of flight.

Exception 8. A property that has achieved national significance within the last fifty years is normally not eligible for NHL designation. However, an event of this time period may have made a property of extraordinary national importance and therefore eligible for NHL designation. It is anticipated that future nominations, such as those associated with the Cold War, will need to address this exception.

A High Degree of Integrity

Properties considered for NHL designation must be associated with one of the NHL criteria and must meet any NHL exceptions. In addition, the property must retain a high degree of integrity. Integrity is defined as the ability of a property to convey its significance. All properties must retain the essential physical features that define both *why* a property is significant (criteria and themes) and *when* it was significant (periods of significance). These are features without which a specific property can no longer be identified such as an airfield associated with flight testing aircraft on the cutting edge of technology between the 1930s and 1950s. The NHL Program recognizes seven aspects or qualities of integrity: location, design, setting, materials, workmanship, feeling, and association.

- *Location* is the place where the historic property was constructed or the place where the historic event occurred. While many properties associated with the American Aviation Heritage context, such as military bases and airports are likely to be in their original location simply because of their size, a home or a laboratory building may have been relocated. Properties that have been moved can be considered for designation under this theme study only if they meet NHL Exception 2 (above).

- *Design* is the combination of elements that create the historic form, plan, space, structure, and style of a property. Design can also be a defining feature in districts, reflected in the way in which the buildings, sites, or structures were related to each other during their historic period of significance. Support structures where research activities took place such as hangars, test fields, flight courses, and wind tunnels must retain their original relationship to each other. The interior design of a building, such as a classroom or office building, must be able to convey its significant function. An aircraft carriers, which often experience extensive renovations over time, may qualify for NHL designation if the carrier retains those features essential to its period of significance and its aviation mission.

- *Setting* is the physical environment of a historic property. It involves how, not just where, the property is situated and its historic relationship to surrounding features and open space. It is important to take into account both the significance of a property and the importance of its setting to that significance when evaluating its integrity of setting. The settings of aviation properties have often changed over time. An open test field since covered with roads and houses will not retain the integrity necessary for NHL designation.

- *Materials* are the physical elements that were combined or deposited during a particular period of time and in a particular pattern or configuration to form a historic property. To retain the high degree of integrity needed for NHL designation, most of the materials from the period of significance must have been preserved, even if the property has been rehabilitated. For example, runways should be of their historic material.

- *Workmanship* is the physical evidence of the crafts of a particular culture or people during any given period in history. This element is most often associated with architecturally important properties. It is the evidence of artisans' labor and skill in constructing or altering a building, structure, object, or site and may be expressed in plain construction or sophisticated detailing.

- *Feeling* is a property's expression of the aesthetic or historic sense of a particular period of time. It results from the presence of physical features that, taken together, convey the property's historic character. For example, an airfield whose 1930s control tower has been modified to a more modern World War II design may have lost its "historic sense of place," while one that retains its original design, materials, workmanship, and setting can still convey the feeling of the golden age of flying.

- *Association* is the direct link between an important historic event or person and a historic property. A property retains its association if it is the place where the event or activity occurred and is sufficiently intact to convey that relationship. Laboratories, for example, have more direct associations with the significant work of important scientists than houses where they only spent their leisure time.

Evaluation against Comparable Properties

Finally, each property being considered for NHL designation must be evaluated against other comparable properties bearing a similar nationally significant association. Comparing individual properties associated with the same event provides the basis for determining which site has an association of exceptional value or quality in illustrating or interpreting the history of American aviation. Analyzing the relative significance for properties being considered for NHL designation is always vital to the evaluation process and, in the case of aviation, is critical given the thousands of existing military bases, airports, and other properties. Most often, considerable research is required to develop the comparative information necessary to determine which property best represents its relevant topic at the national level.

METHODOLOGY

In order to provide a qualitative framework within which a comparative professional analysis of national significance can occur, the objectives of this study were to:

- Provide a contextual framework to evaluate the relative significance of aviation-related properties;
- Establish registration guidelines for evaluating aviation-related landmarks; and
- Identify properties that may meet National Historic Landmark (NHL) criteria.

Contextual Framework

To help organize and focus research efforts on this epic topic, the NHL Program used a comprehensive library of essays on the history of flight developed by the U.S. Centennial of Flight Commission, a group established by Congress in November 1998 under the "Centennial of Flight Commemoration Act" (P.L. 105-389). The essays, compiled in the website: "Born of Dreams—Inspired by Freedom" (www.centennialofflight.gov), describe the dynamic relationship between people, places and events in aviation history. These essays serve as the base, and at times the narrative, for this study's historic contexts.

Based on these essays, the NHL Program narrowed its focus to broad aspects that significantly influenced aviation development. These aspects include the early experimental years, federal regulation, aeronautical technology, commercial aviation, and military aviation. From these aspects, the program developed three parameters. The first parameter limits the context to the study of aeronautics within the earth's atmosphere (the definition of aviation), with the exception of manned balloon flights into the stratosphere. The second parameter sets the study's time frame from 1861, when balloons served as reconnaissance instruments during the Civil War, to the 1970s when a new era in civil and military aviation emerged with the arrival of the jet age and airline deregulation. Lastly, this study does not concentrate on typology, such as hangar construction, due to the large number of property types associated with aviation.

The NHL Program obtained scholars representing varied aviation fields from both the public and private sectors to serve as mentors. They include Roger D. Launius, Chair of the Division of Space History at the Smithsonian Institution's National Air and Space Museum; Janet Bednarek, Professor of History, University of Ohio; Roger E. Bilstein, Professor of History Emeritus, University of Houston-Clear Lake; Joseph J. Corn, Senior Lecturer, Stanford University; Tom Crouch, Senior Curator, Division of Aeronautics at the National Air and Space Museum; Guillaume de Syon, Professor of History, Albright College; and M. Hill Goodspeed, Historian and Head of Artifact Collections, National Museum of Naval Aviation. The scholars reviewed the study's essays and provided an annotated bibliography of sources they felt were the most important works associated with aviation or with particular properties they believed were nationally significant.

Registration Guidelines

Steps taken to produce the registration guidelines focused on the study's historic contexts and properties already recognized for their aviation importance. Within the contexts, we examined milestones and definitive moments in aviation history, identified the types of associated properties, and analyzed the impacts they made at the national level. Historical documentation gleaned from existing NHLs and park units assisted with determining the level of significance a

property should rise to be considered for NHL designation. Properties in the survey are consistent with the types of historic aviation properties identified in the National Register Bulletin entitled, *Guidelines for Evaluating and Documenting Historic Aviation Properties* (1998).

Property Identification

Properties already recognized for their historic significance are those listed in the National Register of Historic Places, designated as National Historic Landmarks, or established as a unit of the National Park System. Three sources provided these properties: *National Landmarks, America's Treasures: The National Park Foundation's Complete Guide to National Historic Landmarks* (2000) by Allen S. Chambers, Jr.; the U.S. Department of the Interior's *The National Parks: Index 2005-2007*, and the National Park Service's web-based travel itinerary "Aviation: From Sand Dunes to Sonic Booms--A National Register of Historic Places Travel Itinerary."

Properties considered for further study came from several sources: the study's mentors, U.S. Air Force cultural resources staff, and State, Federal, and Tribal Historic Preservation Officers. NHL Program staff conducted additional research on recommended properties as well as other properties that emerged from the historic contexts. Consultations with State Historic Preservation Officers (SHPOs), organizations, or direct contact with property owners assisted the NHL Program in verifying whether sites were extant and, to the extent possible, a property's level of integrity.

Only aircraft associated with specific events, such as the Wright brothers' aircraft, are included in the survey results. Outstanding examples of aircraft, such as the modern airline or fighter aircraft, were not included in the survey since identifying the best example across the country as part of the comparison process requires expertise beyond that contained within the NHL Program.

STUDY RESULTS

This section identifies properties associated with events considered nationally significant within the history of American aviation. These properties are divided into three categories: 1) Properties Recognized as Nationally Significant, 2) Properties Recommended for Further Study, and 3) Properties Removed from Further Study. The properties are further divided within each category according to the aviation eras established in the historic contexts. Each listing notes the property name and location (shown in **bold**), the property's associated context or individual (shown in *italics*), and a statement of the property's significance.

PROPERTIES RECOGNIZED AS NATIONALLY SIGNIFICANT

The properties listed below have either been designated by the Secretary of the Interior as a National Historic Landmark (NHL), or established by Congress as a unit of the National Park System. Also included in this category is the period of significance identified in the NHL nomination. Properties with periods of significance spanning over one era are cross-referenced.

The Pioneering Years, 1861-1909

Wright Brothers

Wright Cycle Company and Wright and Wright Printing, Dayton, Ohio (NHL, 1990, Dayton Aviation Heritage National Historic Park, 1992)
Wright Brothers and Experimentation (1895-1897)
From 1895-1897, the Wrights manufactured their own line of bicycles from this building at 22 South Williams Street, contributing to the know-how and financial resources critical to their experiments in aviation. The brothers operated a printing shop on the second floor.

Wright Brothers National Memorial, Manteo, North Carolina (National Memorial, 1953)
Wright Brothers and Experimentation
A sixty-foot granite triangular obelisk atop Kill Devil Hill commemorates the historic place where the Wright brothers experimented with gliding and made the first sustained flight in a heavier-than-air machine on December 17, 1903.

***Wright Flyer III*, Carillon Historical Park, Dayton, Ohio (NHL, 1990, Dayton Aviation Heritage National Historic Park, 1992)**
Wright Brothers and Experimentation (1904-1905)
The 1905 *Wright Flyer III* is the world's first truly practical flying machine. With this airplane, the Wright brothers perfected the technique of flying and developed a utilitarian flying machine that ushered in the aviation age.

Huffman Prairie Flying Field, Wright-Patterson Air Force Base, Fairborn vicinity, Ohio (NHL, 1990; Dayton Aviation Heritage National Historic Park, 1992)
Wright Brothers and Experimentation (1904-1905)
At Huffman Field, between 1904 and 1905, the Wright brothers developed and tested the world's first practical airplane, the *Wright Flyer III*. From this field the brothers also opened a flying school in 1910 and tested airplanes built by The Wright Company through 1916.

The Early Years & World War I, 1909-1918

Wright Brothers

Fort Myer Historic District, Arlington, Virginia (NHL, 1972)
Wright Brothers and Military Aviation (1908-1909)
On September 3, 1908, Orville Wright made the first military test flight of an aircraft from the Fort Myer parade ground (now known as Summerall Field), convincing the public that man could fly. On a subsequent flight, the plane crashed due to a cracked propeller. Months later the Wrights produced the 1909 Wright Flyer, achieving several record-making flights at the parade ground in July 1909. The army formally accepted *Signal Corps Airplane No. 1,* the world's first military airplane, on August 2, 1909.

The Wright Company, Dayton, Ohio (Dayton Aviation Heritage NHP expansion, 2009)
Wright Brothers and Manufacturing (1910-1911)
The American aviation industry had its origins in these two buildings built by Orville and Wilbur Wright between 1910 and 1911 to serve as its permanent factory location. They were the first buildings constructed for airplane manufacture and the planes built there were tested at the Huffman Prairie Flying Field. By 1911, the factory had the capabilities to construct four airplanes a month, the highest airplane production rate in the world.

Huffman Prairie Flying Field, Wright-Patterson Air Force Base, Fairborn vicinity, Ohio (NHL, 1990; Dayton Aviation Heritage National Historic Park, 1992)
Wright Brothers and Pilot Training (1910-1916)
(See listing in The Pioneering Years)

Hawthorn Hill, Oakwood, Ohio (NHL, 1991; Dayton Aviation Heritage National Historic Park expansion, 2009)
Wright Brothers (1912-1948)
This home was designed by the Wright brothers and completed in 1914, two years after Wilbur's death. Orville lived here until 1948.

Military Aviation

Captain Edward V. Rickenbacker House, Columbus, Ohio (NHL, 1976)
Edward Rickenbacker World War I Ace (1895-1922)
From 1895 to 1922, this house was the residence of World War I aviation hero, Eddie Rickenbacker, known as the "American Ace of Aces," who shot down 26 German aircraft in less than six months making him an idol of American youth.

Fort Sam Houston, San Antonio, Texas (NHL, 1975)
Army Training and Military Conflict (1910-1916)
Between 1910 and 1916, this supply base was associated with three prominent events. In 1910, Lt. Benjamin Foulois learned to fly the army's first airplane through mailed correspondence with the Wright brothers. In 1914, experiments conducted here with the Wright biplane led to the establishment of the Signal Corps' aviation section. In 1916, in the United States' first attempt at air warfare, the fort supplied Gen. John J. Pershing with airplanes and pilots during his campaign on the Mexican frontier against Mexico Gen. Francisco "Pancho" Villa.

Pensacola Naval Air Station Historic District, Pensacola, Florida (NHL, 1976; HABS, multiple years)
Naval Aviation Training (1914-1976)
As the first permanent naval air station in 1914, the first navy pilot training center, and the first naval installation center to send navy pilots into combat, Pensacola Naval Air Station holds a seminal role in American naval history. Pensacola eventually became the U.S. Navy's premier training facility. Hurricane Ivan (2004) damaged a large number of buildings in this district. The navy's subsequent demolition of most of the buildings had a devastating effect on the district's historic character. Additional contributing resources were also demolished in recent years. Of the district's original 55 contributing resources; only about 16 are extant.

Village of Columbus and Camp Furlong, New Mexico (NHL, 1975)
Military Air Operations (1916-1917)
In 1916, this property became the first operational airbase in the country. During his expedition to capture "Pancho" Villa, Gen. John J. Pershing sent 1st Aero Squadron aircraft on aerial observations to prevent further raids across the U.S.-Mexico border.

Between the Wars, 1918-1939

Military Aviation

Pensacola Naval Air Station Historic District, Pensacola, Florida (NHL, 1976; HABS, multiple years)
Naval Aviation Training (1914-1976)
(See listing in The Early Years & World War I)

Hangar 9, Brooks Air Force Base, San Antonio, Texas (NHL, 1976)
Army Aviation Training (1918-1945)
Hangar 9 is associated with the army's (Signal Corps Aviation Section) early efforts to rapidly create an effective air force in response to the impetus of war. Built in 1918 on a training field, the frame hangar is both the only surviving building of more than 60 constructed on this base during World War I and the nation's oldest aircraft storage and repair facility.

Hangar No. 1, Lakehurst Naval Air Station, Lakehurst, New Jersey (NHL, 1968)
Naval Lighter-than-Air Experiments (1921-1961)
Commissioned in 1921, Lakehurst Naval Air Station became the hub of naval lighter-than-air experiments for strategic and commercial purposes. In this hangar, the navy assembled *Shenandoah*, the first American-built rigid airship. It was also the homeport for the navy's other rigid airships, the *Akron*, *Macon*, and *Los Angeles*. During the late 1920s, Lakehurst became the American Airship Center, the only stopping point in the country for commercial airships, and in 1937, the German zeppelin *Hindenburg* crashed here as it attempted to land, marking the end of commercial airship travel.

Mitchell (Gen. William "Billy") House, Middleburg vicinity, Virginia (NHL, 1976)
General William "Billy" Mitchell (1926-1936)
General William "Billy" Mitchell, a dominant figure in American military aviation between the two world wars, played a leading role in launching the World War I American aircraft program and later became the unofficial leader in the campaign for air power. Amidst great opposition, Mitchell set out to overhaul the national defense structure while equipping the Air Service with

new bombers and dirigibles and initiating development of the first airways system in the United States. In 1921, Mitchell gained worldwide attention after his bombers demonstrated the value of air power by sinking a captured ex-German battleship and an obsolete American battleship. In 1925 he was court-martialed for his views but was posthumously restored to the service in 1942.

Randolph Field Historic District, San Antonio, Texas (NHL, 2001)
Army Aviation Training; Airfield Design (1928-1950)
Randolph Field played an exceptional role in the development of the air arm of the U.S. Army, which achieved its independence as the U.S. Air Force in September 1947. It was conceived and designed as a model airfield for flight training in the mid-1920s for the fledgling Army Air Corps. The completed "Air City" became the site of unique Air Corps schools for flying training and aviation medicine, as well as a landmark in airfield planning and design. In addition, administrative headquarters at Randolph Field were keystones in the organizational structure of the Army Air Corps and the Army Air Forces. Their roles were pivotal in the army air arm's 40-year campaign to become an independent branch of the U.S. armed forces.

Rogers Dry Lake
Flight Testing and Research (1933-1985)
(See listing in World War II)

Aeronautical Technology

Variable Density Tunnel, Langley Research Center, Hampton, Virginia (NHL, 1985)
Wind Tunnel Research (1921-1940)
Operational in 1922, the variable density tunnel (VDT) was the first wind tunnel in the world to use the principle of variable density air pressure to test scale model aircraft, and became the workhorse in airfoil research (designed to produce lift) during the 1930s. The VDT was a technological jump in American aerodynamic research that had fallen behind European countries prior to World War I, and led to some of the best aircraft in the world. This facility established the National Advisory Committee for Aeronautics (NACA), the parent agency of the National Aeronautics and Space Administration (NASA), as a technically competent research agency.

30 by 60 Foot Full Scale Tunnel, Langley Research Center, Hampton, Virginia (NHL, 1985; HAER, 1995-1996)
Wind Tunnel Research (1931-1985)
In 1931, NACA's first full-scale tunnel went into operation at Langley Memorial Aeronautical Laboratory. Efforts to streamline airplanes and obtain drag reduction hit their zenith in this tunnel. Within the NACA, early wind tunnel tests were collectively referred to as the "drag-cleanup" program, which started in 1938 and lasted essentially through the end of World War II. The drag-cleanup procedures represented an important step in the evolution of mature propeller-driven airplanes. NASA planned to demolish the tunnel at the termination of its current lease to Old Dominion University in August 2009.

Eight-Foot High Speed Tunnel, Langley Research Center, Hampton, Virginia (NHL, 1985; HAER, 1995)
Wind Tunnel Research (1936-1956)
Completed in 1936, this tunnel was the first continuous-flow high-speed wind tunnel able to test large models and actual working parts of airplanes. Its "slotted throat" design added in 1950

made it possible to obtain accurate results in the transonic range (near the speed of sound). The tunnel ceased operation in 1956 and was slated for demolition in July 2009.

World War II, 1939-1945

Military Aviation

Hangar No. 1, Lakehurst Naval Air Station, Lakehurst, New Jersey (NHL, 1968)
Naval Lighter-than-Air Experiments (1921-1961)
(See listing in Between the Wars)

Pensacola Naval Air Station Historic District, Pensacola, Florida (NHL, 1976; HABS, multiple years)
Naval Aviation Training (1914-1976)
(See listing in The Early Years & World War I)

Randolph Field Historic District, San Antonio, Texas (NHL, 2001)
Army Aviation Training; Airfield Design (1928-1950)
(See listing in Between the Wars)

Ladd Field, Fairbanks Vicinity, Alaska (NHL, 1985)
Army Experimentation (1938-1945)
Established in 1940, Alaska's first army air field originally served as a Cold Weather Test Station. It also later served as an air depot for repair and testing of aircraft, and as the principal base in Alaska for the Air Transport Command. In 1942, a lend-lease program transferred nearly 8,000 aircraft to Russian crews for use on the Russian front.

Tuskegee Airmen National Historic Site, Moton Field, Tuskegee, Alabama (National Historic Site, 1998)
Army Training (1940-1945)
The Tuskegee Institute, established by Booker T. Washington in the 1880s to educate African Americans, was the center for African American aviation during World War II and home to the Tuskegee Airmen who became one of the most highly respected U.S. fighter groups of World War II. In 1939, the U.S government passed the Civilian Pilot Training (CPT) Act authorizing selected schools, including the Tuskegee Institute, to provide basic training for black pilots in case of a national emergency. The following year, Tuskegee was authorized to teach advanced CPT courses. At war's outbreak the military chose the Tuskegee Institute to train pilots for the war effort because Tuskegee had the facilities, engineering and technical instructors and a climate well suited for year round flying. Moton Field at the Tuskegee Institute was built between 1940 and 1942.

Rogers Dry Lake, Edwards Air Force Base, California (NHL, 1985)
Flight Testing and Research (1933-1985)
This dry lakebed provided a natural laboratory for the flight testing of aircraft on the cutting edge of aviation technology. Its broad expanse of hardened clay forms the world's largest natural landing field and is the primary resource associated with the formation of Edwards Air Force Base, the world's premier flight testing and research center, and NASA's Dryden Flight Research Center. Notable aircraft tested at Rogers Dry Lake include the Bell XP-59A in 1942, the nation's first and then-secret jet aircraft; the Bell X-1, the first aircraft to travel faster than the

speed of sound in 1947; and the Bell X-15 rocket plane, designed for hypersonic, high-altitude research in the 1960s.

U.S.S. *Yorktown*, Mount Pleasant, South Carolina (NHL, 1986)
Naval Aircraft Carrier (1941-1943)
The USS *Yorktown*, the second Essex class aircraft carrier built, was commissioned on April 15, 1943. The possibility of using airplanes as a naval strike weapon began in the 1920s when aircraft became capable of performing heavy bombardment against land or sea targets. Naval vessels that could carry several squadrons of such aircraft were developed concurrently. The Essex class was the largest class of carriers the United States ever built and over half, including USS *Yorktown*, served in the Pacific Fleet during World War II.

U.S.S. *Intrepid*, New York, New York (NHL, 1986)
Naval Aircraft Carrier (1941-1943)
Launched in 1943, *Intrepid* is the third Essex class aircraft carrier built in the United States and represents the class that formed the core of the fast carrier task forces in the Pacific war. World War II and the carrier campaigns of the Pacific firmly established the role of aviation within naval operations and the aircraft carrier replaced the battleship as the navy's primary strike weapon.

Aeronautical Technology

30 by 60 Foot Full Scale Tunnel, Langley Research Center, Hampton, Virginia (NHL, 1985; HAER, 1995-1996)
Wind Tunnel Research (1931-1985)
(See listing in Between the Wars)

Eight-Foot High Speed Tunnel, Langley Research Center, Hampton, Virginia (NHL, 1985; HAER, 1995)
Wind Tunnel Research (1936-1956)
(See listing in Between the Wars)

Post War & Cold War Aviation, 1945-1978

Military Aviation

Pensacola Naval Air Station Historic District, Pensacola, Florida (NHL, 1976; HABS, multiple years)
Naval Aviation Training (1914-1976)
(See listing in The Early Years and World War I)

Randolph Field Historic District, San Antonio, Texas (NHL, 2001)
Army Aviation Training; Airfield Design (1928-1950)
(See listing in Between the Wars)

Rogers Dry Lake, Edwards Air Force Base, California (NHL, 1985)
Flight Testing and Research (1933-1985)
(See listing in World War II)

United States Air Force Academy, Cadet Area, El Paso, Texas (NHL, 2004)
Air Force Training; Architecture (1958-1968)
The United States reorganized its military under the National Security Act of 1947, establishing the air force as an independent service equal to the army and navy. In 1954, the federal government authorized the creation of the United States Air Force Academy to serve as the primary undergraduate education institution of that new service. Born in the first decade of the Cold War, the academy provided the new military service with a trained and educated officer corps at a time when national policy placed unprecedented emphasis on air power. Built between 1958 and 1968, the campus was designed by Skidmore, Owings and Merrill, and is also significant for its postwar modern movement architecture.

Aeronautical Technology

30 by 60 Foot Full Scale Tunnel, Langley Research Center, Hampton, Virginia (NHL, 1985; HAER, 1995-1996)
Wind Tunnel Research (1931-1985)
(See listing in Between the Wars)

Eight-Foot High Speed Tunnel, Langley Research Center, Hampton, Virginia (NHL, 1985; HAER, 1995)
Wind Tunnel Research (1936-1956)
(See listing in Between the Wars)

PROPERTIES RECOMMENDED FOR FURTHER STUDY

Properties on this study list have strong associations with nationally significant events within the *American Aviation Heritage* context. Thus, this study recommends that these properties be evaluated to determine their relative significance and integrity for NHL consideration. All evaluations must develop a full context associated with their respective significance, ascertain a high degree of integrity, and compare the subject property with others that share the same significance. Placement on this list does not guarantee NHL designation, nor is this an exhaustive list of properties that may be considered for designation under this study.

The Pioneering Years, 1861-1909

Military Aviation

Fort Monroe, Hampton, Virginia (NHL, 1960)
Lighter-than-Air
The role of military ballooning was established in July 1861 when aeronaut John La Mountain successfully completed the first aerial reconnaissance flight from this fort. Designated an NHL in 1960, partly for its association with the Civil War, the fort's nomination should be amended to reflect its ballooning history. The site was slated for closure by the U.S. Army under the Base Realignment and Closure Commission of 2005, and, after September 2011, the Fort Monroe Federal Area Development Authority will manage the site for the Commonwealth of Virginia. A master developer may be retained to develop, manage and market the real property and a leasing/rental office for the small historic town. All the historic buildings will remain.

The Early Years & World War I, 1909-1918

Aeronautical Technology

Washington Navy Yard, Washington, D.C. (NHL, 1976)
Naval Experimentation
The Washington Navy Yard has aviation significance in both 1912 and World War I. In 1912, engineers at the yard's Naval Gun Factory designed and constructed the first air catapult, and on November 12, Lt. Theodore G. Ellyson, the navy's first pilot, made the first successful catapulted flight in an airplane. A forerunner of those used on aircraft carriers, the catapult moved an airplane along a 30-foot track at a speed sufficient to send a plane airborne. During World War I, Dr. Albert F. Zahm, a pioneer in scientific aeronautics, led aerodynamic investigations at the yard until 1930, eventually sponsoring important research in the yard's wind tunnels. Consideration should be given to updating this property's NHL documentation which makes no reference to aviation.

Research & Development

Wingfoot Lake Airdock, Akron, Ohio
Lighter-than-Air Development and Training
Known as the "Kitty Hawk of Lighter-than-Air," Wingfoot Lake (WFL) Airship Base (also known as Naval Air Station Akron), holds a prominent place within the evolution of airships and the navy's fledgling lighter-than-air endeavors. Originating in 1916 as a test and airship assembly center for the Goodyear Tire and Rubber Company, WFL became Naval Air Station

Akron, a construction, test, development and pilot training base for lighter-than-air activity until 1921 when the navy commissioned the Lakehurst Naval Air Station (Hangar No. 1, NHL, 1968). In continuous service as either a military or civilian airship base, WFL is the oldest airship base in the United States. Its airdock, built in 1917, is the primary resource associated with this history. Currently, Goodyear Airship Operations houses its corporate airship flight operations and supporting offices in the 1917 airdock.

Between the Wars, 1918-1939

Between the Wars: Aeronautical Technology

Langley Memorial Aeronautical Laboratory (also known as Langley Aeronautical Laboratory in 1948; and NASA Langley Research Center in 1958), Hampton, Virginia
Wind Tunnel Research
Home to the National Advisory Committee for Aeronautics' (NACA) first laboratory, Langley memorial became the country's most advanced aeronautical test and experimentation facility and reflects the federal government's recognition of the paramount need to advance aeronautical theory. President Woodrow Wilson created the NACA in 1915 in an effort to advance American aviation to the level of European aviation. Completed in June 1920, the laboratory contains three National Historic Landmark wind tunnels that went into operation between 1921 and 1936: the Variable Density Tunnel (NHL, 1985), the 30 by 60 Foot Full-Scale Tunnel (NHL, 1985), and the 8-Foot High-Speed Tunnel (NHL, 1985). With data obtained from Langley's exclusive complex of experimental equipment, American aircraft began to lead the world's airways. (Also see World War II era listing)

California Institute of Technology, Pasadena, California
Georgia Institute of Technology, Atlanta, Georgia
Massachusetts Institute of Technology, Cambridge, Massachusetts
University of Michigan, Ann Arbor, Michigan
New York University, New York, New York
Stanford University, Palo Alto, California
University of Washington, Seattle, Washington
Research & Education
After funding a Guggenheim School of Aeronautics at New York University, Daniel Guggenheim and his son, Harry (a naval aviator during World War I), founded the Daniel Guggenheim Fund for the Promotion of Aeronautics which proved critical to improving the design and construction of aircraft between the wars. From 1926 to 1930, the fund endowed another six schools of aeronautical engineering at the universities listed above. Both the graduates from the Guggenheim schools and the research sponsored and conducted at these institutes made an incalculable impact on the history of American aviation. An NHL nomination will require that all seven schools be compared to ascertain the institution(s) that best illustrates this history. A preliminary study completed for the National Park Service entitled, "Guggenheim Schools Evaluation," (2007) notes that the California Institute of Technology and the Massachusetts Institute of Technology stand out within this group.

Goodyear Airdock, Akron, Ohio (NR, 1973; HAER OH-57, 1985)
Lighter-than-Air
When the Goodyear Zeppelin Corporation constructed this airdock in 1929 it made Akron synonymous with the development and construction of lighter-than-air aircraft At the time of its

construction, it became the largest airdock in the world. On November 20, 1933, the *Century of Progress* stratosphere balloon, designed by renowned scientist Jean Piccard and his brother, Auguste to conduct investigations of cosmic rays, made its second launch from this site (the first launch was from Soldier's Field in Chicago during the Century of Progress exposition). The flight from Akron became the first time an American balloon successfully reached the stratosphere and the first time two Americans traveled into the atmosphere in a pressurized cabin. The navy's USS Akron (1931) and Macon (1933) were built and launched from here.

Guggenheim Airship Institute (also known as the Goodyear Administration Building), Akron, Ohio
Lighter-than-Air
Dedicated in 1932, "[t]he Guggenheim Airship Institute was operated by the University of Akron from 1929 – 1949," and made possible by the Daniel Guggenheim Foundation for the Promotion of Aeronautics to support research into the aerodynamics, construction and development of lighter-than-air craft. Along with administrative offices, the institute housed a variety of laboratories, wind tunnels, and shop areas to pursue lighter-than-air research. The institute closed in 1949 and the building has since been used as a vocational school and currently as a haunted house. This building should be considered jointly with the Goodyear Airdock due to their associated significance and close proximity.

Stratobowl, Rapid City vicinity, South Dakota
Lighter-than-Air
Beginning in the 1930s, the Army Air Corps and the National Geographic Society began testing high-altitude balloons, including *Explorer I* and *II*, in this natural ground hollow to study the performance of equipment and humans flying at stratospheric heights, making it the "Cape Canaveral of its day." The *Explorer* flights made important contributions to aerial photography, atmospheric science and physics, and proved the utility of using pressurized cabins for high-altitude flights. *Strato-Lab* took flight in November of 1956 setting a world-altitude record at 76,000 feet. The launch site is located within the Black Hills National Forest and is owned by the U.S. Department of Agriculture Forest Service and various private parties.

Between the Wars: Commercial Aviation

Wake Island (NHL, 1985)
Trans-Pacific Air Route
Wake Island is one of three islands associated with Pan American's pioneering trans-Pacific air route from California to the Philippines via Midway, Wake, and Guam in 1935, and in 1936, extended its route from Manila to Hong Kong. (Pan American's dream to cross the Pacific coincided with the nation's interest in establishing a commercial presence in Imperial Japan.) Wake Island was designated an NHL for its World War II significance. Ruins of the Pan American hotel, outbuildings, and clipper pier are located on Peale Island, a part of the coral atoll making up Wake Island. The NHL nomination notes some confusion as to whether a seaplane ramp and concrete aircraft parking area on Peale were constructed by Pan American or the navy. Specifically included within the NHL boundary are the ruins of the Pan American Airways establishment, however, since the nomination was undertaken as part of the World War II in the Pacific National Historic Landmark theme study, it devotes just one paragraph to the airline's base. Consideration should be given to amending the nomination to reflect the island's association with Pan American and transpacific flight.

Marine Air Terminal, LaGuardia Airport, Queens, New York (NR, 1982)
Seaplane Development
LaGuardia Airport's Marine Air Terminal was the original airport terminal building constructed near the bay to serve flying boats that dominated international air travel in the 1930s and 1940s. Clipper seaplanes flying from this terminal represented the culmination of seaplane development and inaugurated a new era in commercial flying. Pan American began flying its Clipper seaplanes from LaGuardia to Lisbon on March 31, 1940. When the Clippers became obsolete after World War II, the terminal was converted to a land plane terminal and is the only operating American airport terminal dating from the "Golden Age of the Flying Boat." The three-story domed terminal has an interior rotunda, six gates, and is presently used by commuter airlines, air taxis, private aircraft, a fixed based operator, and a private weather service. A $6.3 million restoration was completed on the airport's 65th anniversary of commercial flight, December 2, 2004.

Newark Airport Administration Building, Newark, New Jersey (Metropolitan Airport Buildings, NR, 1980)
Airway Navigation
Newark Metropolitan Airport opened in 1928, and was a testing ground for airway navigation and safety aids such as night lighting, radio, air traffic control, and instrument flying. The 1934 Administration Building (Building 51) housed the Weather Bureau and Airways Bureau of the Department of Commerce and, in 1935, the first air route traffic control center (ARTCC) in the United States. The art deco building was retired in 1953 and fell into disrepair. In 2000, the SHPO, FAA, and the Port Authority consulted over the effect of a proposed runway extension project on the building's use. The solution involved moving the 33,000-square-foot, 7,000-ton building three quarters of a mile within the airport. A $60 million restoration project was undertaken that included a 66,000-square-foot addition. It now houses administrative offices of Newark Liberty International Airport and the Port Authority.

Between the Wars: Military Aviation

Naval Aircraft Factory, Building 77H/77L, Mustin Field, League Island, Pennsylvania (Philadelphia Naval Shipyard Historic District, NR, 1999)
Manufacturing
Established in 1917 to manufacture seaplanes and flying boats, the Naval Aircraft Factory (NAF) was for almost thirty years the only government-operated naval aircraft production facility in the United States. It served as the center of naval aircraft production during World War I, and manufactured parts for the USS *Shenandoah* (built 1922-1923), the first rigid airship constructed in the United States. Building 77, which served as the aircraft assembly shop, is now known as Building 77H/77L. Building 77L became administrative office space and is listed in the National Register as a non-contributing resource to the Philadelphia Naval Shipyard Historic District. Building 77H is a contributing resource to the district. Included in the integrity assessment should be the masonry and steel-framed additions that adjoin 77H to Building 77L. In 2000, Kvaerner PLC, a private company, started to refurbish sections of the naval shipyard to accommodate their shipbuilding operations.

Naval Research Laboratory, Washington, D.C.
Research & Development: Radar
Radar research and development was conducted here in the mid-1930s, and greatly accelerated during World War II when the value of radar for tracking and identifying ships and aircraft was

recognized. The Naval Research Laboratory (NRL) developed ASB, the first airborne radar in the United States which became the workhorse radar of naval aviation. Also NRL's Identification Friend or Foe (IFF) was the first IFF system to employ separate frequencies for the interrogation of a radar target and for the target's reply signal, which greatly simplified the IFF hardware design. The military's IFF system was the predecessor of the air traffic control radar beacon system (ATCRBS) used extensively in civil aviation.

Air Corps Tactical School, Building 800 (Maxwell Air Force Base Senior Officers' Quarters Historic District; Building 800, Building 836, NR, 1988), Montgomery, AL
Military: Army Training
The Air Corps Tactical School was the first school in the world to teach the tactics and techniques of military aviation and became the center of the revolutionary doctrine of strategic bombing. Based on this doctrine, officers of this school formed the war plan to defeat Hitler. The Air Corps Act of 1926 caused the Air Corps Tactical School to relocate from Langley Field in Virginia, were it had opened in 1920, to Maxwell Field in 1930. New construction for the school included an academic and administration building (Building 800--Austin Hall) and a large number of Officers' Quarters. The Senior Officers' Quarters at Maxwell were constructed from 1932 to 1935 to house teachers and students at the Tactical School.

World War II, 1939-1945

Aeronautical Technology

Langley Memorial Aeronautical Laboratory (also known as Langley Aeronautical Laboratory, 1948; and NASA Langley Research Center, 1958), Hampton, Virginia
Research & Development: Federal Government
Almost all World War II combat aircraft went through tests at Langley, giving them the advantage in performance. In postwar activities, NACA researchers made strides toward aircraft reaching supersonic speeds. Two major developments made efficient transonic flight practical: the area rule and the supercritical airfoil that reduced drag in the transonic engine, both products of the transonic wind-tunnel research directed by aerodynamicist Richard Whitcomb at Langley Memorial Aeronautical Laboratory. This property is also identified in the *World War II and the American Home Front* National Historic Landmarks theme study under the name Langley Research Center. (Also see listing in Between the Wars era.)

Eglin Air Force Base, Fort Walton Beach, Florida (Eglin Field Historic District, NR, 1998)
Research & Development: Military
During World War II, Eglin Field served as the nation's principle station for air warfare experimentation, making major contributions to national defense in the development of tactical strategies, testing of weaponry, and missile research under a wide range of potential combat environments. The district includes the McKinley Climatic Laboratory (NR, 1997), which began testing armaments and materials under a simulated arctic environment in 1947. Eglin Field Historic District contains 20 of the 164 World War II era buildings.

Naval Air Test Center, Patuxent River, Maryland
Research & Development: Naval Aviation
Commissioned on April 1, 1943, Naval Air Station (NAS) Patuxent River became the site of the Naval Air Test Center in 1945, consolidating naval aviation test programs at facilities such as the Washington Navy Yard, the Naval Aircraft Factory in Pennsylvania, and Naval Air Station

Anacostia in Washington, D.C. Known as "Pax River," its Naval Air Warfare Center-Aircraft Division is the world's premier research, development, test and evaluation facility for naval aircraft systems. During World War II, hundreds of combat experienced pilots arrived here to test airplanes. Formalized classroom instruction started in 1948 with the establishment of a Test Pilot Training Division, and in 1958, the U.S. Naval Test Pilot School was established.

Wright Field, Wright Patterson Air Force Base, Dayton, Ohio
Research & Development: Army Aviation (applied technology)
Wright Field is the site of major advances in U.S. aeronautical technology and was the centerpiece for test-flying and improving the performance of virtually all military aircraft designs for the army. The work at Wright Field insured America's air superiority during World War II and was the place for the army where aeronautical engineering technology developed and flourished and became an essential part of America's aeronautical engineering culture, absorbed and assimilated by thousands of aeronautical engineers in industry, government, and academia. Some of the facilities remain in use today for their original research and development purposes.

Radar Station B-71, Redwood National Park, California (NR, 1998)
Research & Development: Radar
The Klamath River Radar Station is significant as rare survivor of a World War II early warning radar station. The property was part of an innovative network of radar stations and ground observers formed to take advantage of newly available radar technology to create a coastal defense system along the Pacific Coast. One of 10 stations covering 1,200 miles form Canada to Mexico, the Klamath River Station was supplemented by 2,400 ground observers, critical in light of Japan's ability to assault American territory with its demonstrated attack on Pearl Harbor and landings in the Aleutian Islands of Alaska. The heavily-guarded station was camouflaged to appear as a farm from the air.

Bell Telephone Laboratory (Bell Labs), Holmdel, New Jersey
Research & Development: Radar
In collaboration with other researchers, Bell Lab scientists advanced electronics, including research and development into microwave radar that proved crucial to the Allied victory in World War II. Radar systems were later modified for civilian use and used to improve navigation and communication along the U.S. airways.

Signal Corps Radar Laboratory, Camp Evans Historic District, Belmar, New Jersey (NR, 2002)
Research & Development: Radar
Camp Evans was the nerve center of the army's secret wartime radar research and development, using and coordinating the work of academic laboratories and private contractors such as Bell Labs, the Massachusetts Institute of Technology's Radiation Laboratory (Rad Lab), Western Electric, and Westinghouse. Here, the army developed and improved the long-wave early warning radar (SCR-268, 270 and 271), and tested radar developed elsewhere, such as the Rad Lab's microwave early warning (MEW) radar and the Identification Friend or Foe (IFF) systems, the predecessor of the air traffic control radar beacon system (ATCRBS) used extensively in civil aviation. Buildings included in the historic district include those of the former Marconi Wireless Telegraph Company of America (1912-1925) and numerous temporary buildings constructed for radar research and development, and post war buildings associated with later army research projects.

Military Aviation

U.S. Naval Air Station Sunnyvale, California, Historic District (NASA Ames Research Center) (NR, 1994)
Lighter-than-Air
During World War II, the field at Sunnyvale, commonly known as Moffett Field, served as the navy's west coast lighter-than-air operations center and as the headquarters for the Commander, Fleet Airships Pacific. It also served as the primary training site for blimp pilots in the United States, all free balloon (untethered) training, and as an assembly center for Goodyear blimps from approximately 1942 to 1944. Now known as the NASA Ames Research Center, NASA administers the field's historic resources including three dirigible hangars: Hangar #1, the original hangar built in 1932 for the storage of the airship *Macon* and training World War II airship pilots, and the World War II era Hangars #2 and #3.

Hangar, New Castle Army Air Base, Wilmington, Delaware
Military Training: Pilot, WAFS
This 1942 hangar is associated with the Women's Auxiliary Ferry Squadron (WAFS), established by the army's Air Transport Command in the fall of 1942 to fly planes from the manufacturers to their permanent bases. The WAFS merged into the Women's Air Forces Service Pilots (WASP) in 1943 and were the first women military pilots to serve with the U.S. Army Air Forces during World War II. Houston Municipal Airport and Avenger Field, in Sweetwater, Texas, the other two sites most closely associated with the WAFS/WASPs, appear to have lost integrity. (*World War II and the American Home Front* National Historic Landmark theme study identifies this hangar as a National Register candidate.)

Wendover Air Force Base, Wendover vicinity, Utah (NR, 1975)
Military Training: Bombardier
Wendover Air Force Base played an important role in training heavy bombardment crews and ushering in the atomic age. First conceived when the air corps commenced an extensive expansion program, Wendover became its choice for a bombing and gunnery range. Crews of the Enola Gay and Bocks Car trained here for the deployment of the two atomic bombs to end the war. The base closed in 1963 and buildings fell into disrepair. The Wendover Airfield Museum has restored the hangars and other buildings.

Post War & Cold War Aviation, 1945-1978

Civil Aviation

Experimental Station (Civil Aeronautics Authority), Indianapolis, Indiana
Air Navigation Aids
This Civil Aeronautics Authority (CAA) facility adjacent to the Indianapolis Municipal Airport opened on May 29, 1939, to improve aviation safety through ultra-high-frequency radio ranges, transmitters, receivers, instrument landing systems, airport lighting methods, and other air navigation aids. The CAA used the airport runway, and its own facilities included a hangar, laboratory, and shop building. The Experimental Station was the center for developing air navigation aids until the late 1950s when it was gradually deactivated. Many of its resources and personnel were transferred to the new National Aviation Facilities Experimental Center (NAFEC) near Atlantic City, New Jersey, established in the summer of 1958.

Aeronautical Technology

Boeing High-Speed Wind Tunnel, Seattle, Washington
Research & Design: Wind Tunnel Development
Built in 1944, Boeing's high-speed wind tunnel is associated with the second design era of aeronautical technology, the jet-propelled airplane. In this tunnel, Boeing tested its jet bomber design designated the XB-47, a revolution in aircraft design. First flown on December 17, 1947, the B-47 became a mainstay of the air force's Strategic Air Command in the 1950s and early 1960s. Extensive use of the wind tunnel from the very beginning of the design process was pivotal to the design's success. In 1953, upgrades to the wind tunnel increased its mach speed from 0.9 to 1.12, gaining the facility its current designation as the Boeing Transonic Wind Tunnel. A series of upgrades began in 1996 to extend the life of the facility another 50 years. Phase Two of a facility modernization program (demolition and reconstruction of the wind tunnel) ended in May, 2001.

General Mills Plants 5 (Fulton Bag Building), 6 (Truman Building), and 7 (Griggs-Cooper Building), and Whitney School, Minneapolis, Minnesota
Lighter-than-Air
General Mills, alongside the University of Minnesota, served as the center for all U.S. balloon work from when ballooning. The company won several contracts through the Office of Naval Research (ONR), and during the post World War II years, dedicated its entire Mechanical Division, to this sole pursuit. General Mills and ONR directed Project *Helios*. Although unsuccessful, *Helios* spawned two highly successful programs; Project *Skyhook,* an unmanned scientific military balloon program, *Strato-Lab,* a manned high-altitude program which produced the balloons used in the famed Stratobowl ascents. Plant 7, the Griggs-Cooper Building, is extant. The SHPO was not able to provide information on the integrity of the University of Minnesota's Whitney School. (Two other buildings associated with the balloon program, Plant 5 (Fulton Bag Building) and Plant 6 (Truman Building), are no longer extant.)

Military Aviation

Offutt Air Force Base, Omaha vicinity, Nebraska (HAER, 2002)
Strategic Air Command
The following three buildings are one-of-a-kind and are nationally significant for their association with the Cold War: the Looking Glass mission operations area, the headquarters building of the former Strategic Air Command (SAC), and the SAC Memorial Chapel.

Looking Glass Operations Area – The operations area is the only physical manifestation of one of the most amazing feats of military aviation logistics. Planes nicknamed "Looking Glass" mirrored ground-based command, control, and communications systems, and could be used in the event that a nuclear bomb destroyed the underground SAC command center at Offutt. From 1961 through 1990 a Looking Glass aircraft, with a full crew of 24, was in the air 24 hours a day, 365 days a year. The building is currently used for air force and naval operations.

Former SAC HQ – This building best represents SAC's preeminent role in the Cold War political and military strategy of Mutually Assured Destruction. The building is currently the headquarters of SAC's successor, the joint Air Force-Navy U.S. Strategic Command.

SAC Memorial Chapel – This building's design includes stained glass iconography depicting the missions of the various SAC Strategic Missile and Bombardment Wings. The chapel is unique as a religious building adorned with grim imagery of global nuclear warfare, such as mushroom clouds and a Red Telephone.

***Saratoga* (CVA 60), Naval Station, Newport, Rhode Island**
Aircraft Carrier Development
Saratoga is one of four of the Forrestal Class carriers built between 1955 and 1959. As the first large postwar super-carrier (attack carrier), the Forrestals provided the design model for all subsequent U.S. carriers. In 1980 this vessel underwent the most extensive industrial overhaul ever performed on any navy ship, and in 1987 was again overhauled at the Norfolk Naval Shipyard at a cost of $280 million. Saratoga was decommissioned in 1994. In January 2000, the navy placed the carrier on donation hold, awaiting transfer as a potential museum or memorial.

Arnold Engineering Development Center (AEDC), Arnold Air Force Base, Tullahoma, Tennessee
Research & Development
AEDC became an early postwar military facility with a complex of specialized wind tunnels and related facilities for the study of high-speed flight and technologies required for the evolution of advanced military aircraft. An outgrowth of the National Unitary Wind Tunnel Act of 1949, the first facility at the AEDC was the Propulsion Wind Tunnel (PWT), and the first test was performed June 1953. The Air Force later added an Aerodynamic Wind Tunnel 4T, situated in the PWT. The entire PWT complex was accepted by the Air Force in January 1961 and has been the facility of choice for considerable wind tunnel work ever since. The AEDC soon became the nation's largest aerospace ground test facility complex with 58 aerodynamic and propulsion wind tunnels, rocket and turbine engine test cells, space environmental chambers, arc heaters, ballistic ranges and other specialized test units. Fourteen of these tunnels are unmatched anywhere else in the world.

Lewis Laboratory (NASA Glenn Research Laboratory), Cleveland, Ohio
Research & Development: Jet Engine
After World War II, American jet engine technology was greatly enhanced by work at the NACA Lewis Aeronautical Laboratory in Cleveland, Ohio. In particular, detailed research on compressor technology led the Lewis Laboratory to publish a definitive series of reports on gas-turbine compressor design considered to be the bible in the field. To this day, detailed jet-engine research continues at the Lewis Laboratory, now renamed the NASA Glenn Research Laboratory in honor of John Glenn.

Jet Age

Grand Canyon Crash Site, Grand Canyon National Park, Arizona
Airway Modernization
A 1956 aviation crash in the Grand Canyon prompted political events that modernized air traffic control systems and aviation safety regulations. On June 30, 1956, a United Airlines DC-7 and a Trans World Airlines Lockheed 1049 collided at 21,000 feet over Grand Canyon National Park, the worst U.S. airline disaster up to that time, killing all 128 passengers and crew. No single event in American history has contributed more to the current system of air safety than the Grand Canyon disaster.

Dulles International Airport, Fairfax and Loudon Counties, Virginia (NR DOE)
Airport Design
Designed by Eero Saarinen, this airport was the first designed as a jetport. When it opened in 1962, Dulles was one of the most modern airports in the world and symbolized America's progress into the jet age. Unique at this airport was the mobile lounge that transported passengers from the terminal to the aircraft.

Lambert-St. Louis International Airport Terminal, St. Louis, Missouri
Airport Design
In 1956, architect Minoru Yamasaki designed a three-domed main terminal building, the forerunner of modern terminal design. The jet age began at Lambert with the inauguration of TWA's Boeing 707 service. (On May 12, 1927, Charles Lindbergh departed from this privately owned airfield for New York to begin the first solo nonstop trans-Atlantic flight. Six months later, the airfield's owner, Major Albert Lambert, sold the airfield to the city, making Lambert-St. Louis Municipal Airport the first municipally owned airport in the country.)

Trans World Airlines Flight Center, Jamaica, New York (NR, 2005)
Airport Design
Opening in May 1962, this center (also known as TWA Terminal 5) at John F. Kennedy International Airport is a significant example of mid-20th century modern architecture, engineering and airline terminal planning, and was designed by Eero Saarinen, one of the preeminent architects of mid-century modernism in America. The terminal was closed in January 2002 and efforts are underway to support the preservation of the property. Jet Blue currently has plans to reuse the property.

Manufacturing

McDonnell Douglas Aircraft Plant, St. Louis, Missouri
Jet Fighter Development
McDonnell Douglas was a major post war supplier of jet fighters for the U.S. Navy. Now the Boeing Aircraft Plant, this site is associated with the development of military and civilian aircraft including the F-4 Phantom that was produced between 1958 and 1979 and retired in 1996. The F-4 Phantom was a phenomenally successful design, representing the growing capabilities as well as the growing electronic complexity of postwar combat aircraft. (The company also built Mercury and Gemini Space Capsules.) The plant is adjacent to Lambert Field.

Bell Aircraft Corporation, Buffalo, New York
Rotary
The Bell Aircraft Corporation manufactured the Huey UH-1H helicopter, the most produced helicopter subtype during the 1960s. Bell is now known as Bell Helicopter Textron and continues to manufacture both civilian and military helicopters.

U.S. Army Aviation School, Fort Rucker, Alabama
Military: Pilot Training
Known as the mecca for army aviators, Fort Rucker has been the home to all U.S. Army flight training since 1971, and a training place for U.S. Air Force helicopter pilots since 1971. In an attempt to rebuild the air corps that the army lost after the air force became independent in 1947, a small group of rebellious army officers developed armed helicopters at Fort Rucker in 1955.

Because of this, the army developed greater air mobility in support of its ground forces during the Vietnam War with the Huey becoming the most symbolic weapon of the war.

PROPERTIES REMOVED FROM FURTHER STUDY

For the benefit of future researchers, this category describes places that no longer exist or which lack the high degree of integrity needed for landmark designation.

The Pioneering Years, 1861-1909

Properties listed in this section are associated with American aviation's early pioneering years of 1861-1909. Exceptional pioneers reflected in this list include Samuel P. Langley, Octave Chanute, Orville and Wilbur Wright, and Glenn Curtiss.

Military Aviation

Fort Corcoran, Arlington, Virginia
Lighter-than-Air
Between September 1861 and August 1863, Aeronaut Thaddeus Lowe chose Fort Corcoran as his base of operations for the Union Balloon Corps during the American Civil War. Lowe made ascensions from the fort on a daily basis and reported observations made to his commanding officers. The fort stood at the present location of Key Boulevard at North Ode Street. An Arlington Historical Society marker demarcates the fort's former location.

***George Washington Parke Custis,* Maryland**
Lighter-than-Air
In 1861, the *Custis* became both the first vessel specifically retrofitted for balloon launching, and the first "aircraft carrier" in American military history when the balloon *Constitution* made an aerial reconnaissance of the southern side of the Potomac River. The SHPO could not determine whether this vessel is extant.

Samuel Langley

Allegheny Observatory, Pittsburgh, Pennsylvania.
Experimentation
Between 1867 and 1886, Samuel Langley, one of American's most accomplished scientists, was professor of physics and director of this observatory where he began his aeronautical career building whirling tables to demonstrate the ratio between power and lift. The original observatory where Langley conducted his experiments was demolished when the current observatory was built.

Smithsonian South Shed, Washington, D.C.
Experimentation
In 1887, Samuel Langley became assistant secretary of the Smithsonian Institution where he received valuable research support in his heavier-than-air flight investigations. Up through 1903, the Smithsonian's carpentry and machine shops in the South Shed (south of the Smithsonian Institution Building, NHL, 1965, commonly known as the Smithsonian Castle) became a research and development facility for the creation of a flying machine, the manned aerodrome. Langley's aerodynamic experiments beginning in 1887 led to his 1891 book *Experiments in Aerodynamics* published by the Smithsonian. This book elevated Langley to world class status among aerodynamic researchers. The shed was demolished in the 1980s on the site where the

Haupt Garden is now located. The Smithsonian preserved most of the machine tools and many of the hand tools and instruments surviving in the old shop.

Langley Aerodrome No. 5
Experimentation
Following his earlier wind studies and experiments with rubber-band-powered models, aviation pioneer Samuel Langley launched *Aerodrome No. 5* on May 6, 1896, from a houseboat on the Potomac River for the first successful flight of an unmanned, engine-driven, heavier-than-air craft of substantial size. *Aerodrome No. 5* is an aircraft of the National Air and Space Museum.

Langley Aerodrome No. 6
Experimentation
After the successful flight of *Aerodrome No. 5*, Langley launched *Aerodrome No. 6* over the Potomac from a houseboat on November 28, 1896, for another successful unmanned flight. *Aerodrome No. 6* was actually the earlier aerodrome model *No. 4* that had been so radically altered it was given the new designation of No. 6. While *Aerodrome No. 5* had squared off wing tips, *No. 6* had rounded wing tips. This is an aircraft of the National Air and Space Museum.

Langley Quarter Scale Aerodrome
Experimentation
Following the successful flights of *Aerodrome Nos. 5* and *6*, Langley proceeded with plans to build a piloted craft. He started with this quarter scale gasoline-powered model that made two flights on June 18, 1901. A final satisfactory flight from a houseboat with a larger engine took place on August 8, 1903, prompting the War Department to allocate $50,000 toward a manned aerodrome (*Aerodrome A* below). This is an aircraft of the National Air and Space Museum.

Langley Aerodrome A
Experimentation
Langley's full scale manned aircraft was launched on October 7 and 8, 1903, from a houseboat on the Potomac River. Both times the aerodrome immediately crashed into the water ending Langley's career in aviation. Despite the outcome, Langley's status as a preeminent scientist, his publications, and his work with manned and unmanned "aerodromes" from 1896-1903 encouraged others, including the Wright brothers, to pursue aeronautic experiments. The aerodrome was restored to its 1903 configuration and is an aircraft of the National Air and Space Museum.

Houseboat, Washington, D.C.
Experimentation
The houseboat from which Samuel Langley made his 1903 attempt to launch, *Aerodrome A*, a full-scale manned aircraft over the Potomac River, was located at the Sixth Street docks until it was destroyed in the 1960s.

Octave Chanute

Miller Beach, Indiana
Experimentation
Engineer Octave Chanute designed and experimented with gliders between 1894 and 1896 to produce the most significant aircraft of the pre-Wright era. In June 1896, on the shores of Lake Michigan on Miller Beach, Chanute and two assistants experimented with a refurbished

Lilienthal glider and a new glider, the *Katydid*, both of which produced disappointing results. Also known as "Chanute Hill," the dune has been covered with roads and houses. A plaque commemorates the spot.

Dune Park, Indiana
Experimentation
At Dune Park, about five miles east of Miller Beach, Octave Chanute and his assistants flew the *Chanute-Herring Biplane* in a second round of test flights from August 21 to September 26, 1896. Designed by Chanute and engineer Augustus Herring, the biplane was the most significant craft of the pre-Wright era. The dune is now covered by the remains of a steel plant and no longer retains integrity due to development.

Chanute-Herring Biplane
Experimentation
Designed by Chanute and engineer Augustus Herring, this glider flew at Dune Park in the summer of 1896. The glider employed a Pratt truss system, a model the Wright brothers would use in constructing their gliders and first airplane, and a system still used in biplane aircraft. This aircraft no longer exists.

Wright Brothers

7 Hawthorne Street, Dayton, Ohio
Experimentation
The Wright brothers' experiments with kites, gliders and fliers at the turn of the century produced the first truly practical flying machine. The residence at 7 Hawthorne Street was the location of the Wright family home in which the brothers did much of the thinking and planning that produced the world's first airplane. In 1937, Henry Ford moved this building to Greenfield Village in Michigan as part of Ford's vision of small-town America. Due to its relocation, the building has lost integrity of location and setting.

1127 West Third Street, Dayton, Ohio
Experimentation
In 1897, the Wrights located their bike company here and in 1899, began using the building for aeronautical experiments and for building gliders and airplanes. After ending the bicycle business in 1908, the brothers continued using the building as a laboratory and after The Wright Company formed, airplane engines were built here. In 1937, Henry Ford moved this building to Greenfield Village as part of Ford's vision of small-town America. Due to its relocation, the building has lost integrity of location and setting.

Kitty Hawk, North Carolina
Experimentation
Due to development, little remains of the original desolate character of this former fishing hamlet associated with the Wright brothers' 1900-1903 early work in experimental aircraft that produced the first flight of an airplane and established the foundation of aeronautical engineering.

1899 Kite
Experimentation
The brothers designed, built, and flew this kite to test their solution to controlling an airplane, called "wing-warping" whereby the wings twisted in opposite directions. As one wing lifted, the other wing lowered. Based on their successful results, the brothers would move on to designing a man-carrying version. This five-foot-wingspan biplane kite broke during an experiment and was destroyed about 1905.

Wright 1900 Glider
Experimentation
Using their wing-warping concept, the Wright brothers produced the first of three full-size, man-carrying aircraft. After testing the craft under various conditions and measuring air resistance (or drag), the brothers found that the craft lacked the lift needed for flight. At the end of the flying season, the brothers determined the glider to be of no further use to them because they planned to build a larger improved glider for the next season. Therefore, they left the glider in a sand hollow where it was eventually destroyed in a gale in 1901.

Wright 1901 Glider
Experimentation
The 1901 glider was the largest then ever flown with a total surface area two and a half times that of the 1900 glider. During test flights, a new problem with lateral control associated with their wing-warping system emerged, and efforts to increase the lift failed, leading the brothers to question the accuracy of the lift and drag data established by earlier experimenters. This glider no longer exists.

Wright 1902 Glider
Experimentation
After conducting their own test with a wind tunnel, the brothers gained new data for the 1902 glider—the world's first aircraft with three-axis control of roll, pitch, and yaw still fundamental in today's aircraft. Their success prompted the brothers to design a powered aircraft. One wing tip from the 1902 machine, in the collection of the National Air and Space Museum, is all that remains of this experimental glider.

Wright 1903 Flyer
Experimentation
The Wright brothers inaugurated the aerial age and the invention of the airplane with their successful first flights of this heavier-than-air powered flying machine at Kitty Hawk, North Carolina on December 17, 1903. The plane sustained damaged while being transported back to the campsite. The Wrights crated the plane and it was never flown again. This is an aircraft of the National Air and Space Museum.

Wright 1904 Flyer II
Experimentation
The Wrights continued their work at Huffman Prairie to develop a more practical airplane. In the *Flyer II*, the Wrights would fly their first complete circle. Problems persisted with control and the brothers decided to redesign the plane. Rather than save the *Flyer II*, the Wrights salvaged portions for the 1905 Wright Flyer (*Wright Flyer III*).

Wright 1908 Military Flyer
Experimentation
The Wright brothers produced this flyer in response to the War Department's request for a two-seat observation aircraft. This wire-braced biplane first flew at Fort Myer, Virginia, on September 3, 1908, and over the following days set new duration records. On September 17, the plane was destroyed in a crash, injuring Orville Wright and killing its passenger, army observer Lieutenant Thomas Selfridge, the first death in a powered airplane accident. The flyer was destroyed in the crash.

1243 West Second Street, Dayton, Ohio
Experimentation
In May 1909, the Wright brothers set up a new work area in the barn behind their brother Lorin's home at this address. It was here that Wilbur and Orville tested a replica of the 1908 propeller that failed during the army flight trials at Fort Myer, Virginia. The building has been demolished.

Wright 1909 Military Flyer
Experimentation
After the crash of the 1908 *Military Flyer*, the Wrights built the 1909 *Military Flyer* using the same engine type used in the 1908 aircraft, but making the wing area smaller and making changes to the rudder and wire bracing. The 1909 *Military Flyer* became the world's first military airplane after meeting and exceeding the army's specifications for an aircraft. The flyer became *Signal Corps No. 1* and was used for flight training in College Park, Maryland, and Fort Sam Houston, Texas, in 1910. In 1911, the War Department approved the transfer of the flyer to the Smithsonian. This is an aircraft of the National Air and Space Museum.

The Early Years & World War I, 1909-1918

College Park Airport, College Park, Maryland (NR, 1977)
Wright Brothers & Pilot Training
Billed as the "World's Oldest Continuously Operating Airport," this flying field was established in 1909 when Orville and Wilbur Wright gave flying lessons to the army's first pilots, becoming the first training site in the country for military fliers. Here Wilbur Wright fulfilled his military contract with the sale of the first military aircraft to teach two military personnel how to fly. In 1911, Congress granted its first funding for aeronautical purposes for construction of an airdrome and flying school at College Park. The Army Signal Corps marked notable achievements here in 1911 that included a 42-mile flight to Fredrick, Maryland; record-breaking altitude flights (3,260 and 4,167 respectively) by Lt. Henry H. Arnold (the future commander of the U.S. Army Air Forces); and testing of a bombsight invented by former army officer Riley E. Scott. In 2003, the National Park Service found that changes to the airport, including the loss of buildings and structures, and the relatively recent introduction of paved runways and taxiways, altered the historic feel and appearance of the early twentieth century airfield to the extent that it no longer retains a high degree of integrity.

Speedwell Motor Car Company, Dayton, Ohio
Wright Brothers & Manufacturing
At the end of 1909, the Wright brothers and a group of New York financiers formed The Wright Company to manufacture aircraft. The company leased space in a corner of this plant for

airplane assembly while The Wright Company manufacturing plant was under construction. This property no longer exists.

Glenn Curtiss

Castle Hill, Hammondsport, New York
Manufacturing
One of the founding fathers of American aviation, Curtiss's aviation achievements would include making the first public flight in the United States, pioneering seaplane and flying boat designs, and becoming the leading aircraft manufacturer in the country by 1914. Glenn Curtiss's aircraft were among the most successful and important aircraft of the era. Curtiss worked from his home, known as Castle Hill. The building no longer exists except for the cupola Curtiss built and began working from in 1906. Referred to as The Annex, the cupola is now located in the Curtiss Museum in Hammondsport.

G. H. Curtiss Manufacturing Company (also known as Curtiss Aeroplane and Motor Company), Hammondsport, New York
Manufacturing
Glenn Curtiss, in partnership with Augustus Herring, formed the first U.S. aircraft company on March 20, 1909, and was a highly competitive brand to the Wright brothers. Beginning in 1909, these facilities manufactured the popular Curtiss airplanes, among the most successful and important aircraft of aviation's early years. Considered the father of naval aviation, in 1911 Curtiss made the world's first flight in a practical hydroplane. Originally consisting of two rows of buildings, only one-half of one factory building remains.

Keuka Lake Area, Hammondsport, New York
Flight Testing and Research
Glenn Curtiss used Lake Keuka as a testing ground to develop aircraft considered among the most successful and important of aviation's early years. While the lake was frozen, Curtiss conducted motor and propeller tests in conjunction with Alexander Bell's Aerial Experiment Association (AEA), an organization formed in 1907 to build a practical airplane. After developing lakefront beaching facilities, in 1911 he pioneered the development of the seaplane including the A-1 *Triad*, the first naval aircraft. Curtiss went on to become the world's leading manufacturer of seaplanes and flying boats. The beaching facilities now lack a high degree of integrity due to the construction of a high school along the slide path aircraft used to access the lake.

June Bug
Air Racing
Glenn Curtiss designed and flew this plane in June 1908 as a member of Alexander Bell's Aerial Experiment Association (AEA) that formed to build a practical airplane. In the *June Bug*, Curtiss won the *Scientific American* trophy for the first officially observed flight in a straight line for one mile. This was the first trophy ever awarded within the American aviation community. (Permanent possession of the trophy could be gained after winning it once a year for three years.) In the later division of the AEA assets, the *June Bug* was apportioned to Curtiss who offered it to the Smithsonian which had no place to exhibit the aircraft. *June Bug* was the only one of the four AEA dromes (the others being *Red Wing, White Wing*, and *Silver Dart*) to not end up in a crash. It rotted away in a storage place at the Keuka lakefront in Hammondsport, New York.

Golden Flyer
Air Racing
After Curtiss won the *Scientific American* trophy with *June Bug* (above), the Aeronautical Society of New York City requested its own aircraft. Curtiss designed this pusher biplane that became the first plane sold to a civil owner in the United States. Built by the Herring-Curtiss Company, Curtiss flew this aircraft to win the second *Scientific American* trophy on July 17, 1909. After flying the *Golden Flyer* at Minneola, New York, for the Aero Club, Charles Willard took the airplane on a tour, during the course of which he made appearances in Athens, Pennsylvania; Richmond, Virginia; Toronto, Canada; and Letonia, Kentucky. He flew the machine at the Dominguez Field meet in Los Angeles on January 10-20, 1910, and then sold it to a carnival for a static tent exhibition. It disappears from history thereafter. (Tom Crouch, e-mail correspondence, June 27, 2005

Reims Racer
Air Racing
After Glenn Curtiss delivered the *Golden Flyer* (above) to the Aero Club of America, the organization chose him to be the only American participant in the first international aviation meet in France in August 1909. For this meet, Curtiss flew his newly designed *Reims Racer*. Similar to the *Golden Flyer*, the *Reims Racer* had a shortened wing span. At the meet, Curtiss won the Gordon Bennett Aviation Cup for flying the fastest average speed. After his triumph in France, Curtiss took the flyer to Brescia, where he won the Grand Prize and an altitude prize. Returning to the United States, he flew the aircraft at the Dominguez Meet in Los Angeles, then leased it to Charles Hamilton, who crashed in the water during a Seattle flight. Recovered and rebuilt, the airplane was leased to Charles Willard, who operated it through late 1910, after which it disappears.

Glenn Curtiss House, Miami Springs, Florida (NR, 2001)
Glenn Curtiss continued his career in aviation manufacturing aircraft until 1920 when the company underwent financial reorganization. He then left New York and settled in this home where he became a real estate developer and lived until his death in 1930. Since this property is not associated with Curtiss's career in aviation, no further action is recommended.

Rotary

Menlo Park Laboratory, Menlo Park, New Jersey (Thomas A. Edison Memorial Tower, NR, 1979)
Experimentation: Rotary Flight
In 1876, from Menlo Park Laboratory, Thomas A. Edison experimented with helicopter technology, becoming one of the first to realize that a large-diameter rotor with a low blade area was needed to give good hovering efficiency. Edison's scientific approach proved that vertical flight required both high aerodynamic efficiency of the rotor and high power from an engine. The building no longer exists and its site is commemorated by the Thomas A. Edison Memorial Tower.

Military Aviation, 1909-1918

U.S.S. *Birmingham*
Experimentation: Naval Aviation
On November 14, 1910, Eugene Ely, a member of Glenn Curtiss's commercial flying team, flew a Curtiss pusher biplane from this scout cruiser in the first ever shipboard aircraft takeoff conducted in response to the Navy Department's interest in having a plane fly from a ship. This pioneering act of flying was immensely significant to the future of maritime power. The U.S.S. *Birmingham* was sold for scrap in 1959.

Greenbury Point, Annapolis, Maryland
Experimentation: Naval Training
Greenbury Point was the navy's first air station for its first formal aviation training program in the early 1910s. At Greenbury Point pilots flew the navy's first aircraft (the A-1 *Triad*), made long distance flights and established endurance records, and conducted experiments with wireless communication and visual navigation techniques. Greenbury Point also contained the Engineering Experimental Station at the Naval Academy for experiments in aviation development. In 1914, a larger naval aeronautic center was established in Pensacola, Florida, for year-round aviation experiments and training. A wooden hangar and wing with office space, workshop and barracks associated with the camp in 1911 no longer exists. Greenbury Point is now managed as a conservation area and is used for light midshipmen tactical training.

U.S.S. *Pennsylvania*
Experimentation: Naval Aviation
Following his successful take-off from the U.S.S. *Birmingham* two months earlier, the navy proposed that Eugene Ely land a plane on board ship. On January 18, 1911, Ely landed a Curtiss biplane on the deck of the warship U.S.S. *Pennsylvania* anchored off the San Francisco waterfront, resulting in the introduction of aircraft to the navy. One day later the navy's first aviator began flight instruction. This cruiser was sold for scrap in 1931.

U.S. Army Rockwell Field Historic District, North Island, San Diego, California, (NR, 1991)
Military Training: Army Pilot Training
This airfield served as the Rockwell Field Army Air Service installation from 1917 to 1935 after President Woodrow Wilson signed an executive order condemning the land for army and navy aviation schools. Rockwell was one of four primary flying schools established to produce desperately needed military pilots for World War I. The school moved here from its original 1913 location on North Island when it was known as the Signal Corps Aviation School, the army's first permanent flying school, and moved from this location in 1935 when the navy took over jurisdiction of all of North Island. Due to building and setting alterations the property no longer maintains a high degree of integrity.

Between the Wars, 1918-1939

Airmail

West Potomac Park Polo Grounds, Washington, D.C. (Non-contributing site, East and West Potomac Parks Historic District, NR, 1973)
Airmail
On May 15, 1918, the polo grounds served as a terminus on the nation's first regularly scheduled airmail route between New York and Washington, D.C., establishing the feasibility of airmail. Although the polo grounds have been in use since 1908, they do not contribute to the East and West Potomac Parks Historic District because they consist of open fields with no associated, recognizable structures, and have been significantly altered over time through the construction and demolition of a parking lot and several buildings. The Aero Club of Washington erected a bronze plaque in 1958, the 40-year anniversary, to honor the site's association with airmail.

Elko Regional Airport, Elko, Nevada
Airmail
In 1926, Elko was an airmail station on the first transcontinental route operated by the U.S. Post Office, and, with its dirt runways, was the terminus of the first commercial airmail flight in the northwestern United States. Following the Kelly Act of 1925, which authorized private carriers to fly the mail, Walter T. Varney of Varney Speed Lines obtained the contract airmail route from Pasco, Washington, to Elko, Nevada. A hangar constructed in 1922 is still in use at the airport according to the Air Mail Pioneers organization. The city built a new terminal in 2001, and today the airport has two runways in operation, one for commercial flights and one for general aviation.

Airmail Hangar, Bryan, Ohio
Airmail
Bryan, Ohio, was a fuel stop on the original transcontinental airmail route between Cleveland, Ohio, and Chicago, Illinois. The c. 1918 airmail hangar here was the first constructed in the country by the Post Office and was demolished in 1998.

Bustleton Field, Philadelphia, Pennsylvania
Airmail
Bustleton was the midpoint stop between New York and Washington, D.C., on the nation's first regularly scheduled airmail route, inaugurated in 1918. Pilots leaving from Washington, D.C. and Elmont, New York landed here to refuel their planes, deliver mail, and collect more mail. This airfield no longer exists.

Belmont Park Race Track, Elmont, New York
Airmail
Belmont Park is significant for its association with the first regularly scheduled airmail service in the United States started on May 15, 1918 between New York and Washington, D.C. Belmont was chosen as the New York terminus for its open space and stands for spectators. Belmont closed in 1963 due to structural deterioration. A $30 million facelift rebuilt the grandstand, club house and other public conveniences. The park's original racing strips, 1 ½-mile main course, cottages, barns, and other architectural and landscaping elements remained intact. Belmont opened on May 20, 1968, and is still in operation. However, the new racetrack was built on top

of the field used by the early exhibition and airmail pilots and therefore no longer retains integrity.

Checkerboard Flying Field, Maywood (Chicago), Illinois
Airmail
Checkerboard Flying Field, a commercial airport, opened in 1919 and was leased by the U.S. Post Office Department from 1920 to 1922 to serve as Chicago's airmail terminal on the transcontinental airmail route that would become the nation's first lighted airway. The success of the first transcontinental airmail flight is credited to Jack Knight, who piloted airmail's first night flight, landing at Checkerboard on February 23, 1921. In 1922, the Post Office relocated to more spacious, government-owned land across the street at what became known as the Maywood Government Field (see below). Checkerboard remained a commercial airport until 1928. A hangar and a repair hangar were built in 1920, and a larger hangar was moved here from a former army airfield in June 1921. The original repair hangar burned. Existence of remaining hangars is unknown. From 1923 to 1928, Yackey Aircraft Company manufactured aircraft at Checkerboard. The site of Checkerboard Field is presently Miller Meadow and part of the Cook County Forest Preserve. A stone marker in the meadow commemorates the airmail pioneers.

Maywood Government Field, Hines (Chicago), Illinois (Buildings 20 & 21 determined eligible for NR listing, 1980)
Airmail
The U.S. Post Office Department used the Maywood Government Field as an airmail terminal between 1922 and 1927, when the site served as the terminus for all government/ airmail flights in and out of Chicago on the transcontinental route. Two 1921 buildings originally used by the U.S. Air Mail Service are rare survivors from the pioneering days of aviation and airmail, and may be the earliest extant structures in the United States associated with a stop on the original transcontinental airmail route. Robertson Aircraft Company, whose chief airmail pilot was Charles Lindbergh, inaugurated contract airmail service between Chicago and St. Louis on April 15, 1926, from this site. The Government Civil Aviation Board declared the field unsafe for private and commercial use in 1927, at which time the Post Office turned over airmail routes to private carriers and relocated operations to the Chicago Municipal Airport. The site of the Maywood Government Field and its associated buildings are today occupied by the Hines Veterans Administration, the Loyola Medical Center, and the Cook County Forest Preserve. The two 1921 buildings were transferred to the Veterans Administration, reconditioned, and are presently used for storage and repair of x-ray equipment. An original engraved stone plaque on the front wall of Building 20 reads "U.S. Air Mail Service." The grass airfield no longer exists. Integrity of airmail buildings since the 1980 determination of eligibility (DOE) is currently unknown.

Iowa City Municipal Airport and Boeing/United Airmail Hangar, Iowa City, Iowa
Airmail
On January 8, 1920, Iowa City was the only stop on the first airmail flight from Chicago to Omaha, and in February 1921, it was designated as a fuel stop on the first transcontinental day/night airmail attempt. Pilot Jack Knight landed here on February 21 during a snow storm, refueled, and continued his flight from North Platte, Nebraska, to Chicago (see North Platte Airport and Checkerboard Field). His success helped secure congressional funding for permanent transcontinental airmail service. When the Kelly Act of 1925 transferred airmail service from the U.S. Post Office to commercial carriers, Boeing Air Transport assumed responsibility for delivering the mail and operating the airport in Iowa City. A Boeing/United

airmail hangar constructed at this airport in 1930, formerly one of seven original airmail hangars still standing (Iowa City, Iowa; Cheyenne, Wyoming; Crissy Field, California; Elko, Nevada; Omaha, Nebraska; Rock Springs, Wyoming; and North Platte, Nebraska), was demolished in 2008. Built largely of brick on a metal frame, the hangar represented one of the largest clear-span enclosed spaces built up to that time. The runway has been extended and a terminal was built in 1951.

College Park Airport, College Park, Maryland (NR, 1977)
Airmail
College Park served as the headquarters for the first airmail flights operated by the U.S. Post Office Department, when it took over service from the Army on August 12, 1918, and was used for airmail operations until 1921 when the New York – Washington, D.C., airmail route was cancelled in favor of transcontinental service. A 1919 airmail hangar was remodeled in 1968 and 1974. The National Park Service sponsored an NHL nomination for the airport, but evaluation of the property's integrity suggested that the conversion of the site from a grass field to concrete runways, and the absence of substantial surviving resources from the pre-World War II period of significance had compromised the site so that it no longer conveys its association with the first quarter century of powered flight.

Hazelhurst Field, Mineola, New York
Airmail
Hazelhurst was an important departure point and terminus for transcontinental and transatlantic airmail. The airfield was the departure site of the first transcontinental airmail flight in September 1920 and the terminus of the first day/night transcontinental airmail flight in February 1921. Hazelhurst closed in 1951 to make way for the first shopping mall in the United States.

Offutt Field and Air Mail Hangar (Facility #29), Fort Crook (now Offutt Air Force Base), Omaha vicinity, Nebraska
Airmail
The U.S. Post Office used this army airfield as an important hub (refueling stop) during the pioneering years of airmail service until 1930, at which time airmail operations moved to Omaha's new municipal airport. The success of the first transcontinental airmail flight is credited to Jack Knight, who landed and refueled at Offutt Field in February 1921 en route from North Platte, Nebraska, to Chicago. Built in 1925, the hangar has since been modified into a two-story office building.

Marina Airfield, San Francisco, California
Airmail
Marina Airfield was the first terminus of the U.S. Post Office Department's Transcontinental Air Mail Service. The first scheduled mail plane landed here on September 9, 1920. In 1936, the Air Mail Pioneers organization erected a memorial plaque on the base of a flag pole to honor this event. The site ceased being a civil airfield in the early 1940s, and is presently a city-owned recreational park known as Marina Green.

McCook Field, Kettering Park (Dayton), Ohio
Airmail: Lighted Airway
The army's experimental lighted airway between McCook Field and Norton Field, 80 miles away, became the model the Post Office used for its plan to light the transcontinental airmail route during the early 1920s. The first United States military aviation research center operated

here from 1917 to 1927 and became a center of both theoretical work and empirical testing of airframes, engines and aeronautical equipment of every description. In 1927, the army moved its facility from McCook to Wright Field (now Wright-Patterson AFB). A housing project, athletic field, and shopping center now occupy the former McCook Field.

Hadley Field, South Plainfield, New Jersey
Airmail
Hadley Field was the first eastern terminus for night airmail service. The Post Office leased the land on November 1, 1924, and set up radio masts, boundary lights, floodlights and revolving beacons to prepare the turf (unpaved) field for operation. The inaugural night airmail flight departed Hadley Field for Cleveland on July 1, 1925. Revolutionary four-course radio range equipment was installed at Hadley Field in 1928. Hadley Field operated as a general aviation field until it closed in 1968. The site was redeveloped and is presently occupied by an office park and a hotel.

Civil

Aeromarine Plane and Motor Company, Keyport, New Jersey
Commercial Aviation
This company is associated with pioneering air carrier Aeromarine, which probably contributed more to the development of commercial passenger air transportation than any other operation at that time, and was the only passenger service to flourish for any length of time in the first decade following World War I. Aeromarine-related aircraft manufacturing companies continued using the facilities well into the 1930s and the airfield was last used in the late 1930s. The Aeromarine Plane and Motor Company consisted of several large factory buildings and an unpaved NE/SW runway between the factory buildings and Raritan Bay. At least some factory buildings remain, however, two hangars are dilapidated and the former unpaved runway is now a street. New construction on the street's east side has altered the design and feeling that the runway ever existed.

Ford Airport, Dearborn, Michigan
Commercial Aviation: Airport
Ford Airport opened in 1924 as the country's first modern airport and in 1929 set the standard for paved runways. Such runways became a necessity as aircraft became larger and heavier and as airlines began to fly under more weather conditions. To handle flights under rainy or snowy conditions, airports needed more durable and easily maintained landing surfaces. Although other airports had experimented with runway preparations using cinder, gravel and asphalt, Ford Airport set the standard in 1929 when it installed a 75-foot-wide, 2,500-foot-long concrete runway. The Ford Proving Ground facility at this location has removed any trace of the former runways.

Hazelhurst Field, Mineola, New York
Airfield
Hazelhurst was an important terminus and departure point for military, and record-setting speed and distance flights during the golden age of aviation. The airfield was established in 1911 and became an army flying field in 1917. Hazelhurst remained an active military airfield through World War II, and closed in 1951 to make way for the first shopping mall in the United States.

Cutting Crash Site, north of Kirksville, Kansas
Federal Regulation Development
In the pioneering era of federal regulation of U.S. domestic air commerce, the crash of a DC-2 at this site on May 5, 1935, altered how the federal government regulated aviation. The crash killed five people, including U.S. Senator Bronson M. Cutting from New Mexico, prompting a congressional investigation. The event underscored the growing public concern over air safety, and the need for both better ground-to-air communications and an air traffic control system. The ensuing 1938 Civil Aeronautics Act replaced the Bureau of Air Commerce (under the Department of Commerce) with a newly created independent agency, the Civil Aeronautics Authority (CAA). The CAA was also given authority to set airline fares and routes, functions previously held by the Post Office and the Interstate Commerce Commission. Because no wreckage or evidence of the crash exists at the site, it appears to lack a high degree of integrity.

Rotary

USS *Bunker Hill* (CV-17)
Army: Rotary
The first shipboard trials conducted with a helicopter took place aboard the tanker the USS *Bunker Hill* anchored two miles east of Stratford Point Light, Connecticut. Col. Frank Gregory of the Army Air Corps completed 20 flights from the tanker, illustrating the helicopter's capacity to land on a small strip of deck only 78-feet in length. The USS *Bunker Hill* was scrapped in 1973.

Airways

Mitchel Field, Long Island, New York
Research & Development: Radio
Established in 1917, Mitchel Field was the site of the first blind landing piloted by Lt. Jimmy Doolittle, on September 24, 1929. In a biplane equipped with an Aircraft Radio Corporation radio range receiver, Doolittle took off, flew a prescribed course, and landed using instruments only (i.e. no visual navigation). Public pressure over several aircraft crashes, noise, and the small size of the field, forced Mitchel to close in 1961. Following urban development, only parts of two runways exist along with portions of the hangar line and buildings erected during a substantial 1929-1932 construction project.

Manufacturing

Pitcairn-Cierva Autogiro Company, Philadelphia, Pennsylvania (Autogiro Company of America)
Manufacturing: Rotary Development
In the fall of 1929, the Pitcairn-Cierva Autogiro Company became the first company to manufacture autogiros in the United States after Harold Pitcairn purchased the U.S. rights to Juan de la Cierva's inventions. By 1931, Pitcairn had built 51 autogiros and developed a number of models for both the U.S. Navy and some private owners. A clutch Pitcairn incorporated into the autogiro's design allowed the later development of a jump-takeoff autogiro in the 1930s. No resource connected with this company has been identified.

Pitcairn Field, (Bryn Athyn), Willow Grove, Pennsylvania
Manufacturing: Rotary Development
On December 18, 1928, Frank Pitcairn completed the first successful rotary-wing flight (in a C-8 autogiro) in the United States at this field, and during the 1930s, developed and manufactured numerous autogiro models here. The landing strip consisted of a mowed area and a single wooden hangar. In 1942, the navy acquired Pitcairn Field for its World War II buildup and today the site is home to the Naval Air Station Joint Reserve Base Willow Grove. The property no longer retains a high degree of integrity due to its transformation into a naval air station.

Exell Helium Plant, Amarillo, Texas (HAER, 2004)
Lighter-than-Air
In the 1920s and 30s the Amarillo area became the lone supplier of helium for the U.S. Navy's fleet of blimps and dirigibles, including the *Macon* and the *Akron*, the navy's. During World War II, Exell was known as the "crown jewel" among the four helium plants constructed to meet the increased demand for helium. Helium was used as well in the development of the atomic bomb. A complex of more than 20 buildings and structures made up the facilities. Between 1980 until its closure in 1996, Exell remained the sole federally operated helium plant. All the helium-producing equipment was auctioned in 2000 and only the buildings remain. Exell lacks integrity of feeling due to the loss of the plant's equipment.

Amarillo Helium Plant, Amarillo, Texas (HAER, Bureau of Mines Helium Activities, 1998-2001)
Lighter-than-Air
The Amarillo Helium Plant, built by the Bureau of Mines between 1928 and 1929, was the first of its kind in the United States. During the 1920s and 1930s, the Amarillo area became the sole supplier of helium used for lighter-than-air craft, giving the U.S. a virtual world monopoly on helium. It produced helium well into the 1970s and served as both the headquarters and the research and development center for the entire federal helium program until 1996. The site consisted of more than 15 buildings and structures including an administration building, storage tanks, laboratories and a boiler house. The General Services Administration auctioned the plant as surplus government property due to excessive deterioration. The new owners are using the former helium plant as an industrial park.

Development

College Park Airport, College Park, Maryland (NR, 1977)
Aids to Navigation
Many important developments in aeronautical technology took place at College Park. Here, researchers and pilots experimented with wireless radio communications, made the first reported nighttime landing with the aid of acetylene lamps on the ground, and developed the first radio navigational aides for all weather flying. The National Bureau of Standards used College Park for its applied aeronautical research activities during the late 1920s and early 1930s, and developing the first radio navigational aids for use in "blind" or bad weather flying, the forerunner of the modern Instrument Landing System. An NHL nomination found that the conversion of a grass field to concrete runways and the absence of substantial surviving resources from the pre-World War II period of significance have compromised the site's ability to convey its association with the first quarter century of powered flight.

Soldier Field, Chicago, Illinois (NHL, 1987, de-designated, 2006)
Lighter-than-Air
Soldier Field, formerly Grant Park Stadium, is the site of the first flight of the *Century of Progress*, a balloon with a pressurized and sealed gondola designed to make the first American sponsored trip to the stratosphere in 1933. The national significance of the formerly designated NHL is not associated with its aviation history. Due to a rehabilitation project completed in 2003, Soldier Field was de-designated.

Bellefonte Field, Bellefonte, Pennsylvania
Airways and Radio Range Development
Bellefonte was located in the "hell stretch" of the Allegheny Mountains along the New York-Cleveland-Chicago airmail route (along which the greatest number of airmail pilots lost their lives), and was probably the most used intermediate landing field in the 1920s and 1930s. Bellefonte was used as a testing ground by the National Bureau of Standards for the four-course radio range, which became operational here in 1928, making the New York-Cleveland airway the first of any appreciable distance to have a continuous radio-marked course. In 1932, Bellefonte was chosen as one of three original weather radio stations on transcontinental route. A Pennsylvania Historical and Museum Commission marker commemorates the site of the former airfield on which a high school presently stands.

Airports

Western Air Express Airport, Albuquerque, New Mexico
Airport
This airport is associated with Western Air Express airline, a powerful influence during the pioneering years of passenger service. This airline began passenger service on May 23, 1926, about one month after winning a contract airmail route to become one of the country's five big airlines. In the 1930 airmail contract awards, Postmaster Walter Brown insisted that Western Air Express and Transcontinental Air Transport merge for the central transcontinental mail route as part of his master plan for the nation's airways. The merger produced Transcontinental and Western Air Inc. (TWA). A 1929 directory identifies the airport as the Western Air Express Airport with four intersecting runways in the shape of an eight-point star. Later directories (1933 and 1938) identify the property as the Transcontinental & Western Air Airport, and thereafter until 1944 as the West Mesa Airport. The former airport now consists of a single building and a portion of the four runways. The property no longer retains a high degree of integrity due to new development over the original runways.

Washington National Airport, Arlington, Virginia (Washington National Airport Terminal and South Hangar Line, NR, 9/12/97)
Airport
A New Deal initiative, National Airport was the country's first fully federally constructed commercial airport. Built by the Works Progress Administration (WPA), it opened on June 16, 1941. The terminal was the first airport of the nation's capital and remains in operation today. The footprint, massing, floor plan and diamond-shaped control tower design of the terminal building, as well as the runway configuration, runway lengths and advanced lighting and instrument landing systems were reportedly innovations that influenced airport design throughout the country. Property lacks high integrity primarily due to the loss of the control tower.

Cheyenne Airport, Cheyenne, Wyoming (Boeing/United Airlines Terminal Building, Hangar and Fountain, NR, 1985; HAER, 1998)
Airport
Cheyenne was one of the nation's earliest airports and a major component of the original transcontinental airmail route and passenger route from the 1920s through World War II. After Boeing Air Transport Company obtained the airmail contract from Chicago to San Francisco in 1927, it chose the Cheyenne airfield as its main overhaul, and, in 1929, the business changed its name to United Aircraft and Transport Company. United Airlines was created in 1931 and by 1933 the company moved all of its major maintenance and overhaul activities to Cheyenne. Buildings in Cheyenne were constructed between 1929 and 1934. United Airlines constructed the fountain in 1934 as a memorial to early aviation. The airport began a slow decline following the advent of the 42-passenger, DC-4, an aircraft that could fly high enough to cross the Rockies. The property no longer retains a high degree of integrity due to the replacement in 1998 of the hangar's glass and steel sliding doors with windowless, insulated, steel bi-fold doors and conversion in 1960 and 1985 of the terminal building into office space.

North Platte Regional Airport, Lee Bird Field, North Platte, Nebraska
Airport: Airmail
This airport was constructed in 1921 with private funds to serve the needs of the U.S. Air Mail Service, and is associated with the nation's first night airmail flight in February 1922 that helped secure funding for permanent transcontinental airmail service. The Air Mail Pioneers organization reports that an early airmail hangar is still in use at the North Platte Airport, but was moved from the south to the north side of the field to protect it from flooding by the Platt River. The airfield was purchased by the City of North Platte in 1929 and leased to the Boeing Transport Company, who assumed responsibility for airmail service after the Kelly Act of 1925 and is one of the entities which later merged to form United Airlines. The airport has been operated as an Airport Authority since July 1963. Airport improvements over time have altered its 1920s setting.

Grand Central Air Terminal (Grand Central Airport), Glendale, California
Airport Development
The airport was the west coast terminus for Transcontinental and Western Air's pioneering coast-to-coast route. Dedicated in 1929 and owned by the Curtiss-Wright Company, the terminal closed in the late 1950s because its runways could not accommodate the larger jet planes of the period. The Disney Corporation purchased the airport area in the late 1990s with plans to turn the property into a corporate campus. Original one- and two-story archways in the terminal have been filled and a portion of the control tower altered. Of the two remaining hangars, one has been extensively modified for use as a cold storage facility, and the second is used for commercial purposes. The former airport now sits in a densely developed area, and the former runways are no longer discernable. Property lacks a high degree of integrity in design, setting, and materials.

Guam (War in the Pacific National Historic Park, 1978)
Trans-Pacific Route
Part of Pan American's clipper base for its pioneering Pacific route in the era of the flying plane was located on Guam. During World War II the Pan American Skyways Hotel served as a residence for Japanese Naval officers during the occupation. Fire destroyed the building during the American liberation bombardment.

Midway, Midway Islands (World War II Facilities at Midway, NHL, 1987)
Trans-Pacific Route
Midway is associated with Pan American's aviation record as the first airline to cross the Pacific from California to the Philippines via Midway, Wake, and Guam. A flight to Manila in 1935 established transpacific airmail service. According to the National Register documentation, Pan Am established a small hotel and flight facilities on Midway's Sand Island. Seaplane runways in the lagoon were constructed as part of a civil works project in 1938. On December 7, 1941, two Japanese destroyers set fire to the seaplane hangar and shells hit the Pan Am radio station. A historic preservation plan for the Midway Atoll National Wildlife Refuge (1999) prepared for the USDI Fish and Wildlife Service indicates that no historic resources predating 1940 are located on this island.

Pan American Seaplane Base and Terminal Building (Dinner Key), Miami, Florida (NR, 1975; HABS, 1981)
Pan American & Juan Trippe
Completed in approximately 1934, Pan American's Dinner Key base was the largest and most modern marine air terminal in the world. This elaborate flying boat terminal designed by Delano and Aldrich of New York is where Pan American began its international flights and has been described as the "Air Gateway between the Americas." The building is also associated with aviation pioneer Juan Trippe, head of Pan American Airways. In 1954, the building was adapted for use as Miami's City Hall. Due to alterations, the former base and terminal building no longer retain a high degree of integrity.

Port Columbus Airport Control Tower, Columbus, Ohio (NR, 1979)
Airport
The original 1929 terminal and control tower at Port Columbus International Airport is one of the earliest extant airport facilities in the country. Dedicated on July 8, 1929, Charles Lindbergh encouraged the City of Columbus to build this terminal as the eastern transfer point for the Transcontinental Air Transport's (TAT) air/rail cross-country service, marking a definitive step in the progress of civil aviation in the United States. For this service, passengers traveled by rail during the night and by air during the day. The railway station was adjacent to the terminal. The old air terminal is now located at the southeast corner of Port Columbus International Airport. The property no longer retains a high degree of integrity due to alterations. Additions surround three sides of the terminal and three sides of the control tower remain visible.

Aeronautical Technology

Propeller Research Tunnel, Langley Research Center, Langley, Virginia
Wind Tunnel Evolution
A major aerodynamic breakthrough in the era of the mature propeller-driven airplane took place in this tunnel. The NACA cowling research was the first major test program to be carried out in the newly operational (1927) Propeller Research Tunnel (PRT). In less than a year the NACA had designed a cowling, a metal covering for the engine, which initially showed a dramatic 60-percent reduction in drag. Aircraft equipped with this cowling produced many new speed records and within several years virtually all new American airplanes powered by radial engines used NACA cowlings. In January 1930, the National Aeronautic Association awarded the NACA the Collier Trophy for the greatest achievement in American aviation in 1929. This tunnel was demolished in 1950 to make way for the Eight-foot High Speed Tunnel (NHL, 1985).

Hamilton Standard, East Hartford, Connecticut
Research & Development: Propellers
In 1929, Frank Walker Caldwell, America's leading propeller engineer and designer during the aeronautical design revolution of the 1920s and 1930s, joined Hamilton Standard Propeller Corporation in 1929. Between 1929 and 1938, Caldwell oversaw the invention, development, and innovation of the controllable-pitch and constant-speed propellers. In the process, Caldwell pioneered the fundamental propeller testing facilities and techniques needed for successful engineering development. Caldwell's variable pitch propeller, which changes the pitch of the propeller blades (the angle at which they cut through the air) in order to produce more thrust, maximized the performance of revolutionary aircraft such as the Boeing Model 247 and the Douglas DC-2 for which the National Aeronautics Association awarded Caldwell and Hamilton Standard the 1933 Collier Trophy for that year's most important achievement in American aviation. Virtually the entire air force frontline inventory during World War II employed hydromatic propellers developed by Caldwell and Hamilton Standard that changed blade angle automatically according to engine speed. The company moved to Windsor Locks, Connecticut in 1952 and in 1999 merged with Sundstran Corporation to become Hamilton Sundstran. This building could not be located.

Military Aviation, 1918-1939

Hangar 5, Patterson Field (Wright-Patterson Air Force Base), Dayton, Ohio
Rotary Training
The first military Autogiro School established in the United States opened at Patterson Field on April 20, 1938. The four-week course was held in Hangar 5 which served as a classroom and workshop. According to the History Office at Wright-Patterson Field, Hangar 5 was housed in a wooden hangar dating from 1917 or 1918. By the end of World War II, all the wooden hangars at Patterson Field were gone.

World War II, 1939-1945

Manufacturing

Building No. 105, Boeing Airplane Company ("Red Barn"), Seattle, Washington (NR, 1971)
Military Aircraft
This first home of the Boeing Airplane Company founded in 1916 is associated with the design of significant Boeing aircraft including the famous B-17 and B-29 bombers that helped the Allies win World War II. Boeing sold Building No. 105 to the Port of Seattle in 1970, and was moved in the 1970s from its original location to the Museum of Flight south of Seattle in the city of Tukwila, Washington. It has been restored and reopened as part of the museum. Due its move to a modern museum complex, the building no longer retains a high degree of integrity in its setting.

Platt-LePage Aircraft Company, Eddystone, Pennsylvania
Military Aircraft: Rotary
Platt-LePage was one of the earliest companies to advance from autogiro designs to helicopter and other rotary wing engineering. Laurence LePage, who designed the first line of autogyros (K-2, K-3 and K-4) for Kellett Autogyro, and Haviland Platt, a mechanical engineer and patent expert who had several rotary wing patents, formed this company in 1938. Platt-LePage won a

contract from the Air Corps in 1940 and began building the XR-1 helicopter and patented the first tilt-rotor aircraft design in the United States. The company's small size and lack of capital and orders for military aircraft forced Platt-LePage to shut down in 1946. The facilities are no longer extant.

Douglas Aircraft Company, Santa Monica, California
Airliners and Military Aircraft
The production site recalls a remarkable era in prewar, wartime, and postwar aviation, leading into the jet era of the 1960s. The Santa Monica production facilities produced a family of historic Douglas airliners, beginning with the DC-3 in the late 1930s. This design became the workhorse of airlines in America as well as overseas. During World War II, it achieved iconic status as the C-47. In the wake of Pearl Harbor, Donald Douglas wanted to camouflage his plant to protect it from an air attack. With the help of Warner Bros. Studios, the aircraft production facilities and runways were made to blend into the adjacent Sunset Park neighborhood. Production of the DC-3 resumed in the postwar years, although it was soon replaced on the assembly lines by a series of classic, four-engine airliners with piston engines: the DC-4, -6, and -7 series. In the 1940s and 1950s, these stately airliners represented the majority of aircraft in the fleets of major airlines in the U.S. as well as foreign operators. In the 1970s Douglas consolidated its operations at Long Beach Airport and the entire Santa Monica plant was demolished.

Aeronautical Technology

Radiation Laboratory, Massachusetts Institute of Technology (MIT), Cambridge, Massachusetts
Radar
In October 1940, MIT was chosen as the site of an independent laboratory to develop radar for military use. The Rad Lab designed almost half of the radar deployed in World War II, created

over 100 different radar systems, and constructed $1.5 billion worth of radar. An important legacy of the Rad Lab was the establishment of strong institutional links between government, industry, and academia. The post-war years witnessed an increase in large-scale government support of scientific research. The Rad Lab formally closed on December 31, 1945. In its wake remained tons of surplus equipment and the concept for a basic research center that became MIT's Research Laboratory of Electronics. The Rad Lab was located in Building 20, a temporary war building that was used until the late 1990s for an assortment of laboratories, organizations, student groups, and offices. Building 20 was recently demolished to make way for the Ray and Maria Strata Center, a new complex of buildings.

Military Aviation, World War II

Marine Corps Air Facility Santa Ana (National Register, 1975; also known as Lighter-than-Air Ship Hangars), California
Lighter-than-Air
Marine Corps Air Facility Santa Ana became the Marine Corps' primary west coast helicopter base operating Medium & Heavy Transport & Attack Helicopter squadrons during the Korean War and after. The base currently retains excellent integrity but the two World War II era hangars, later used for helicopter storage, are in imminent danger of being demolished. The

blimp mooring pad was also used for helicopter parking. One of the wooden hangars has been relocated to Orange County and the other, Hangar 29, will be torn down for a housing development. The base closed down in 1999 under the Base Realignment and Closure Act.

United States Coast Guard Air Station Brooklyn (Naval Air Station New York), Hangar (Building 25), Brooklyn, New York (Floyd Bennett Field Historic District, NR, 1980)
Rotary Flight
The first helicopter training facility established in the world was founded on November 19, 1943 in a hangar at Floyd Bennett Field that served as the U.S. Coast Guard Air Station Brooklyn from 1938 to 1997, under the auspices of the navy. In January 1944, the first helicopter life saving rescue operation took place in Jamaica Bay off Floyd Bennett field, with the helicopter proving its worthiness for search and rescue work and foreshadowing its utility as a "flying ambulance." The field was used as a center for the development and testing of Sikorsky helicopters and played an important role in the development of search and rescue tools, such as the winch, which evolved into standard helicopter equipment. After deactivation in 1998, the Coast Guard Air Station Brooklyn was transferred to the New York Police Department Aviation unit.

Avenger Field, Sweetwater, Texas
Air Force Training: Women Pilots
The Women's Auxiliary Ferrying Squadron and Women's Flying Training Detachment merged on August 5, 1943, to become the Women Air Force Service Pilots (WASP). More than 1,000 WASPs trained at Avenger Field, the only military flying school for women in the United States. The runways, some World War II hangars, and a fountain (once used to dunk women pilots as an initiation ritual and bearing a wartime plaque from General "Hap" Arnold, commander of Army Air Forces, commending the WASP contribution to the war effort) are extant. This property no longer retains a high degree of integrity due to changes to the setting.

Naval Station, Anacostia, Maryland
Naval Pilot Training
The Naval Station Anacostia was established in 1918 as a World War I air station on land owned by the army, and became a pilot training site with the construction of Bolling Field east of the navy's field. During the inter-war years, the station served as a navy aircraft testing facility. During World War II, nearly 2,000 aviation cadets received primary flight training at the station. At its peak 1,000 personnel were assigned to the station including more than 200 WAVES (Women Accepted for Volunteer Emergency Service). *A Historic Context for DoD Facilities: World War II Permanent Construction* (Goodwin and Associates, 1994) found "the installation as a whole and the individual permanent World War II buildings no longer retain sufficient integrity to convey their association as a World War II military air station."

Houston Hobby Airport, Houston, Texas
Air Force Pilot Training: Women
The Hobby Field site dates from 1928, and became Houston Municipal Airport in 1937. During 1942-43, the airport served as the first training location for the WASP, who later relocated from the crowded commercial airport to Avenger Field. After Southwest Airlines began intrastate service from Hobby in 1971, the airfield experienced impressive growth. The Houston Aeronautical Heritage Society began restoration of the 1940 terminal/control tower in 2003. Property appears to lack integrity according to the *World War II and the American Home Front* National Historic Landmarks theme study.

United States Coast Guard Cutter *Cobb*, Long Island Sound, New York
Rotary Flight
The *Cobb* played an important role in how the U.S. Coast Guard pioneered the use of helicopters for the military. The 1906 *Cobb*, originally a coastal passenger ship, is significant for its association with rotary aviation. After being outfitted as the world's first helicopter carrier, test flights beginning in April 1944 proved the viability of "dipping sonar" on helicopters for anti-submarine hunting and the ability to perform air-sea rescue. On June 19, 1944, Cdr. Frank Erickson, the first pilot trained by the Coast Guard, made the first landing on Cobb's deck. The Cobb was decommissioned on January 31, 1946 and was subsequently sold and scrapped in 1947.

Post War & Cold War Aviation, 1945-1978

Military Aviation

Clinton County Army Air Field, Wilmington vicinity, Ohio
Research & Development
Following the war, this air field became the home of the USAF's Experimental All Weather Flying Program, with a mission to provide test data on aircraft flying under adverse weather conditions. The first major operational implementation of information derived from the all-weather tests occurred in 1948-49 with Operation Vittles, during the Berlin Air Lift, which demonstrated the feasibility of sustained, round-the-clock mass movement of cargo by air. The operation gave aircrews and ground personnel invaluable experience in bad weather flying, air traffic control, and aircraft maintenance – technology which transitioned into the civilian world and improved the commercial airline business by enabling airlines to maintain a regular flight schedule. The air force expanded the existing runway in 1958/1959. The base closed in 1972 and the site is now the Wilmington Air Park/Airborne Commerce (or Airborne Air Park) and operates as a freight shipping company. The property no longer appears to have a high degree of integrity due to a recent runway extension, a new parallel runway, and new maintenance hangars. Also located in the airpark are several large warehousing buildings.

***Forrestal* (CVA 59), Naval Station, Newport, Rhode Island**
Naval Aviation: Aircraft Carrier Development
This aircraft carrier is one of four of the *Forrestal* Class built between 1955 and 1959. As the first large postwar super-carrier (attack carrier), the *Forrestals* provided the design model for all subsequent U.S. carriers. The *Forrestal* was the first carrier built with an angled flight deck which allows simultaneous takeoffs and landings, and has four catapults and four deck edge elevators to move aircraft from the hangar bays to the flight deck. A 28-month, $550 million Service Life Extension Program (SLEP) completed in 1985 completely emptied the carrier and most major equipment was removed for rework or replacement. The navy decommissioned *Forrestal* in 1993, and it is currently designated for disposal as a fishing reef for fishery propagation and accessibility to divers. Of the three remaining *Forrestal* Class carriers, the *Saratoga* is listed above, and the *Independence* and the *Ranger* remain on the naval reserve fleet.

Aeronautical Research

Winzen Research, Inc., Minneapolis, Minnesota
Lighter-than-Air
Winzen Research established itself as one of the world's first plastic balloon companies and is the balloon firm most involved with early manned flights in the United States. Considered one of the foremost companies in the development and research of plastic balloons along with General Mills, Winzen pioneered the use of polyethylene balloons.

RAND, Santa Monica, California
Military Technological Development
Since World War II, RAND, the original "think tank," has played a critical role in the formation of pivotal technological developments, particularly during the Cold War era. With the assistance of Department of Defense planners, the air force established Project RAND (using the acronym for R&D) as a think tank to consider national security options and the range of technologies that might be needed for implementation in the future. RAND began in March 1946 as a freestanding division within the Douglas Aircraft Company and became independent of Douglas in May 1948. Reports from RAND continued to influence a broad range of defense policies and the evolution of aerospace technologies. Originally located in a Douglas Aircraft office between 1945 and 1947, RAND moved to a downtown building that was demolished after RAND relocated to its own building in 1953. RAND's interdisciplinary philosophy was so vital to its operation that it became the primary concern in the architecture of the purpose-built facility. The layout of the building essentially ensured that researchers from different fields would meet face-to-face in the course of a daily basis. RAND built and moved into another highly innovative building just south of the old building in December 2004, and the old building was demolished in 2006.

TABLE 1. THE PIONEERING YEARS, 1861-1909

Properties Recognized as Nationally Significant	Properties Recommended for Further Study	Properties Removed from Further Study
Huffman Prairie Flying Field Fairborn Vicinity, OH *Wright Brothers & Experimentation (1895-1897)*	Fort Monroe Hampton, VA *Military: Lighter-than-Air*	7 Hawthorne Street Dayton, OH *Wright Brothers & Experimentation*
Wright Brothers National Memorial Manteo, NC *Wright Brothers & Experimentation*		1127 West Third Street Dayton, OH *Wright Brothers & Experimentation*
Wright Cycle Company and Wright and Wright Printing Dayton, OH *Wright Brothers & Experimentation (1904-1905)*		1243 West Second Street Dayton, OH *Wright Brothers & Experimentation*
Wright Flyer III Dayton, OH *Wright Brothers & Experimentation*		1899 Kite *Wright Brothers & Experimentation*
		Allegheny Observatory Pittsburgh, PA *Samuel Langley & Experimentation*
		Chanute-Herring Biplane *Octave Chanute & Experimentation*
		Custis, George Washington Parke MD *Military: Lighter-than-Air*
		Dune Park, IN *Octave Chanute & Experimentation*
		Fort Corcoran Arlington, VA *Military: Lighter-than-Air*
		Houseboat Washington, DC *Samuel Langley & Experimentation*
		Kitty Hawk, NC *Wright Brothers & Experimentation*
		Langley Aerodrome No. 5 *Samuel Langley & Experimentation*

Properties Recognized as Nationally Significant	Properties Recommended for Further Study	Properties Removed from Further Study
		Langley Aerodrome No. 6 *Samuel Langley &* *Experimentation*
		Langley Aerodrome A *Samuel Langley &* *Experimentation*
		Miller Beach, IN *Octave Chanute &* *Experimentation*
		Smithsonian South Shed Washington, DC *Samuel Langley &* *Experimentation*
		Wright 1900 Glider *Wright Brothers &* *Experimentation*
		Wright 1901 Glider *Wright Brothers &* *Experimentation*
		Wright 1902 Glider *Wright Brothers &* *Experimentation*
		Wright 1903 Glider *Wright Brothers &* *Experimentation*
		Wright 1904 Flyer II *Wright Brothers &* *Experimentation*
		Wright 1908 Military Flyer *Wright Brothers &* *Experimentation*
		Wright 1909 Military Flyer *Wright Brothers &* *Experimentation*

TABLE 2. THE EARLY YEARS & WORLD WAR I, 1909-1918

Properties Recognized as Nationally Significant	Properties Recommended for Further Study	Properties Removed from Further Study
Fort Myer Historic District Arlington, VA *Wright Brothers & Military Aviation (1908-1`909)*	Washington Navy Yard Washington, DC *Naval Experimentation*	Castle Hill Hammondsport, NY *Glenn Curtiss & Experimentation*
Fort Sam Houston San Antonio, TX *Army Training & Military Conflict (1910-1916)*	Wingfoot Lake Airship Base Akron, OH *Lighter-than-Air Development & Training*	College Park Airport College Park, MD *Wright Brothers & Pilot Training*
Hawthorn Hill Oakwood, OH *Wright Brothers*		Curtiss, Glenn, House Miami Springs, FL *Glenn Curtiss*
Huffman Prairie Flying Field Fairborn Vicinity, OH *Wright Brothers & Pilot Training (1910-1916)*		G. H. Curtiss Manufacturing Company Hammondsport, NY *Glenn Curtiss & Manufacturing*
Pensacola Naval Air Station Historic District Pensacola, FL *Naval Aviation Training (1914-1976)*		*Golden Flyer* *Glenn Curtiss & Experimentation*
Rickenbacker, Captain Edward V., House Columbus, OH *Edward Rickenbacker World War I Ace (1895-1922)*		Greenbury Point Annapolis, MD *Military: Naval Training & Experimentation*
Village of Columbus and Camp Furlong NM *Military Air Operations (1916-1917)*		*June Bug* *Glenn Curtiss & Experimentation*
Wright Company, The Dayton, OH *Wright Brothers & Manufacturing (1910-1911)*		Keuka Lake Area Hammondsport, NY *Glenn Curtiss & Experimentation*
		Menlo Park Laboratory Menlo Park, NJ *Thomas A. Edison: Rotary Experimentation*
		Reims Racer *Glenn Curtiss & Experimentation*
		Speedwell Motor Car Company Dayton, OH *Wright Brothers & Manufacturing*

Properties Recognized as Nationally Significant	Properties Recommended for Further Study	Properties Removed from Further Study
		U.S.S. *Birmingham* *Glenn Curtiss & Experimentation*
		U.S.S. *Pennsylvania* *Military: Naval Experimentation*

TABLE 3. BETWEEN THE WARS, 1918-1939

Properties Recognized as Nationally Significant	Properties Recommended for Further Study	Properties Removed from Further Study
30 by 60 Foot Full Scale Tunnel Hampton, VA *Wind Tunnel Research (1921-1940)*	Air Corps Tactical School, Building 800 Montgomery, AL *Military: Army Training*	Aeromarine Plane and Motor Co. Keyport, NJ *Commercial*
Eight-Foot High Speed tunnel Hampton, VA *Wind Tunnel Research (1936-1956)*	California Institute of Technology Pasadena, CA *Research & Education*	Air Mail Hangar Bryan, OH *Airmail*
Hangar No. 1 Lakehurst, NJ *Naval Lighter-than-Air Experiments (1921-1961)*	Georgia Institute of Technology Atlanta, GA *Research & Education*	Amarillo Helium Extraction Plant Amarillo, TX *Manufacturing – Lighter-than-Air*
Hangar 9 San Antonio, TX *Army Aviation Training (1918-1945)*	Goodyear Airdock Akron, OH *Lighter-than-Air*	Belmont Park Race Track Elmont, NY *Airmail*
Mitchell (Gen. William "Billy") House Middleburg, VA *General William "Billy" Mitchell (1926-1936)*	Guggenheim Airship Institute Akron, OH *Lighter-than-Air*	Bellefonte Field Bellefonte, PA *Airways: Radio Range Development*
Pensacola Naval Air Station Historic District Pensacola, FL *Naval Aviation Training (1914-1976)*	Langley Memorial Aeronautical Laboratory Hampton, VA *Wind Tunnel Research*	Boeing/United Airlines Terminal Building, Hangar and Fountain Cheyenne, WY *Civil: Commercial Service*
Randolph Field Historic District San Antonio, TX *Army Aviation Training (1928-1950); Airfield Design*	Marine Air Terminal, LaGuardia Airport Queens, NY *Commercial: Seaplane Development*	Bustleton Air Field Philadelphia, PA *Airmail*
Rogers Dry Lake Edwards AFB, CA *Flight Testing & Research (1933-1985)*	Massachusetts Institute of Technology Cambridge, MA *Research & Education*	Checkerboard Flying Field Maywood, IL *Airmail*
Variable Density Tunnel Hampton, VA *Wind Tunnel Research (1921-1940)*		College Park Airport College Park, MD *Airmail* *R&D: Aids to Navigation*
		Cutting Crash Site Kirksville, KS *Civil: Federal Regulation*
		Elko Regional Airport Elko, NV *Airmail*

Properties Recognized as Nationally Significant	Properties Recommended for Further Study	Properties Removed from Further Study
	Naval Aircraft Factory League Island, PA *Manufacturing*	Exell Helium Plant Amarillo, TX *Manufacturing: Lighter-than-Air*
	Naval Research Laboratory Washington, D.C. *R&D: Radar*	Grand Central Air Terminal Glendale, CA *Civil: Airport Development*
	New York University New York, NY *Research & Education*	Guam *Commercial: Trans-Pacific Route*
	Newark Airport Administration Building Newark, NJ *Airway Navigation*	Hadley Field South Plainfield, NJ *Airmail*
	Stanford University Palo Alto, CA *Research & Education*	Hamilton Standard East Hartford, CT *R&D: Propeller Development*
	Stratobowl Rapid City vicinity, SD *Lighter-than-Air*	Hangar 5 Dayton, OH *Military: Autogiro Training*
	University of Michigan Ann Arbor, MI *Research & Education*	Hazelhurst Field Mineola, NY *Airmail & Civil*
	University of Washington Seattle, WA *Research & Education*	Iowa City Municipal Airport and Boeing/United Air Mail Hangar Iowa City, IA *Airmail*
	Wake Island *Commercial: Trans-Pacific Air Route*	Marina Airfield San Francisco, CA *Airmail*
		Maywood Government Field Hines, IL *Airmail*
		McCook Field Kettering Park, OH *Lighted Airway*
		Midway Midway Islands *Commercial Aviation: Trans-Pacific Route*
		North Platte Regional Airport North Platte, NB *Airmail*
		Mitchel Field Long Island, NY *Airways: Radio Development*

Properties Recognized as Nationally Significant	Properties Recommended for Further Study	Properties Removed from Further Study
		Offutt Field and Air Mail Hangar Omaha vicinity, NV *Airmail*
		Pan American Seaplane Base and Terminal Building Miami, FL *Commercial: Pan American & Juan Trippe*
		Pitcairn-Cierva Autogiro Company Philadelphia, PA *Manufacturing - Rotary*
		Pitcairn Field Willow Grove, PA *Technology R&D - Rotary*
		Port Columbus Airport Control Tower Columbus, OH *Civil Aviation: Air-Rail Cross Country*
		Propeller Research Tunnel Langley, VA *Wind Tunnel Evolution*
		Soldier Field Chicago, IL *Lighter-than-Air*
		Washington National Airport Arlington, VA *Airport Development*
		West Potomac Park Polo Grounds Washington, D.C. *Airmail*
		Western Air Express Airport Albuquerque, NM *Commercial Aviation*
		USS *Bunker Hill* *Military Aviation: Rotary*

TABLE 4. WORLD WAR II, 1939-1945

Properties Recognized as Nationally Significant	Properties Recommended for Further Study	Properties Removed from Further Study
30 by 60 Foot Full Scale Tunnel Hampton, VA *Wind Tunnel Research (1931-1985)*	Bell Telephone Laboratory Holmdel, NJ *R&D: Radar*	Avenger Field Sweetwater, TX *Army Training: WASP*
Eight-Foot High Speed Tunnel Hampton, VA *Wind Tunnel Research (1936-1956)*	Eglin Air Force Base Fort Walton Beach, FL *Military: R&D*	Building No. 105, Boeing Airplane Company ("Red Barn") Seattle, WA *Manufacturing: Aircraft*
Hangar No. 1 Lakehurst, NJ *Naval Lighter-than-Air Experiments (1921-1961)*	Hangar Wilmington, DE *Army Pilot Training: WAFS*	Douglas Aircraft Company Santa Monica, CA *Manufacturing: Aircraft*
Ladd Field Fairbanks vicinity, AK *Military Aviation*	Langley Memorial Aeronautical Laboratory Hampton, VA *R&D*	Houston Hobby Airport Houston, TX *Army Training: WASP*
Pensacola Naval Air Station Historic District Pensacola, FL *Naval Aviation Training (1914-1976)*	Naval Air Test Center Patuxent River, MD *Naval Aviation: R&D*	Marine Corps Air Facility Santa Ana CA *Military Training: Rotary*
Randolph Field Historic District San Antonio, TX *Army Aviation Training (1928-1950); Airfield Design*	Radar Station B-71 Redwood National Park, CA *R&D: Radar*	Naval Station Anacostia, MD *Military: Pilot Training*
Rogers Dry Lake Edwards AFB, CA *R&D, Military Aviation*	Signal Corps Radar Laboratory Belmar, NJ *R&D: Radar*	Platt-LePage Aircraft Company Eddystone, PA *Manufacturing: Rotary*
Tuskegee Airmen National Historic Site Tuskegee, AL *Military Aviation: Training*	U.S. Naval Air Station (NASA Ames Research Center) Sunnyvale, CA *Naval Aviation: Lighter-than-Air*	Radiation Laboratory, (MIT) Cambridge, MA *R&D: Radar*
U.S.S. *Intrepid* New York, NY *Naval Aviation: Aircraft Carrier*	Wendover Air Force Base Wendover vicinity, UT *Air Force Aviation: Bombardment Training*	United States Coast Guard Air Station Brooklyn *Training: Rotary, Search & Rescue*
U.S.S. *Yorktown* Mount Pleasant, SC *Naval Aviation: Aircraft Carrier*	Wright Field Dayton, OH *Army Aviation: Applied Technology*	United States Coast Guard Cutter *Cobb* Long Island Sound, NY *R&D: Rotary*

TABLE 5. POST WAR & COLD WAR AVATION, 1945-1978

Properties Recognized as Nationally Significant	Properties Recommended for Further Study	Properties Removed from Further Study
30 by 60 Foot Full Scale Tunnel Hampton, VA *Wind Tunnel Research (1931-1985)*	Arnold Engineering Development Center Tullahoma, TN *Air Force R&D*	Clinton County Army Air Field Wilmington vicinity, OH *Military R&D*
Eight-Foot High Speed Tunnel Hampton, VA *Wind Tunnel Research (1936-1956)*	Bell Aircraft Corporation Buffalo, NY *Manufacturing: Rotary*	*Forrestal* (CVA 59) Newport, RI *Military: Aircraft Carrier*
Hangar No. 1 Lakehurst, NJ *Naval Lighter-than-Air Experiments (1921-1961)*	Boeing High Speed Wind Tunnel Seattle, WA *Technology: Wind Tunnel Development*	RAND Santa Monica, CA *R&D*
United States Air Force Academy El Paso, TX *Air Force Training (1958-1968), Architecture*	Dulles International Airport Fairfax & Loudon Counties, VA *Airport Design: Jet Age*	Winzen Research, Inc. Minneapolis, MN *R&D: Lighter-than-Air*
Pensacola Naval Air Station Historic District Pensacola, FL *Naval Aviation Training (1914-1976)*	Experimental Air Station Indianapolis, IN *Civil: Air Navigation Aids*	
Randolph Field Historic District San Antonio, TX *Army Aviation Training (1928-1950); Airfield Design*	General Mills Plants 5, 6, and 7, and Whitney School Minneapolis, MN *R&D: Lighter-than-Air*	
	Grand Canyon Crash Site Grand Canyon National Park, AZ *Airway Modernization*	
	Lambert-St. Louis International Airport Terminal St. Louis, MI *Airport Design: Modern*	
	Lewis Laboratory (NASA Glenn Research Laboratory) Cleveland, OH *Technology: Jet Engine Development*	
	McDonnell Douglas Air Craft Plant St. Louis, MI *Manufacturing: Jet Fighters*	
	Saratoga (CVA 60) Newport, RI *Naval Aviation: Aircraft Carrier Development*	

Properties Recognized as Nationally Significant	Properties Recommended for Further Study	Properties Removed from Further Study
	Trans World Airlines Flight Center Jamaica, NY *Airport Design: Modern*	
	U.S. Army Aviation School Fort Rucker, AL *Pilot Training: Rotary*	

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APPENDIX A. MENTOR BIOGRAPHIES

Janet R. Daly Bednarek is a professor of history and former chair in the History Department at the University of Dayton. She received her Ph.D. from the University of Pittsburgh. She is the author or editor of several books and articles on urban and aviation history including *America's Airports: Airfield Development, 1918-1947* (2001), *Reconsidering a Century of Flight* (2003), and *Cities Take Flight: A Centennial History of the American Municipal Airport* (2004). She is currently at work on a study of airports in the United States since 1947.

Roger E. Bilstein is professor of history emeritus at the University of Houston-Clear Lake, a suburban, upper-division campus for juniors, seniors, and master's level students where he taught courses in twentieth century American history, technology, and foreign relations, as well as aviation and aerospace history. He has written numerous articles and essays on aerospace history that have appeared in scholarly journals and reference works published in America and overseas. He is also the author or co-author of eight books, including *Flight in America: From the Wrights to the Astronauts,* and *The American Aerospace Industry: From Workshop to Global Enterprise*. The latter was cited by the American Library Association as one of the outstanding academic books of 1997. Dr. Bilstein has served as consultant/guest curator for aviation history exhibits at several museums in the United States.

Joseph J. Corn is a senior lecturer at Stanford University, where he has been since 1980. His specialties include the history of technology and he has published a number of books including *The Winged Gospel: America's Romance with Aviation* (rev. ed. 2002) and, with Brian Horrigan, *Yesterday's Tomorrows: Past Visions of the American Future* (reprint ed., 1996). He is presently completing a history of consumer involvement with complex, personal technologies, including sewing machines, computers, and automobiles.

Tom Crouch is senior curator of the Division of Aeronautics at the Smithsonian's National Air and Space Museum. He has served both the National Air and Space Museum (NASM) and the National Museum of American History (NMAH) in a variety of curatorial and administrative posts. He holds a Ph.D. in history from the Ohio State University (1976), and is the author or editor of more than a dozen books and many articles on the history of flight for both popular and scholarly publications. His best known books include: *The Bishop's Boys: A Life of Wilbur and Orville Wright* (1989), *Eagle Aloft: Two Centuries of the Balloon in America* (1983); *Bleriot XI: The Story of a Classic Airplane* (1082); *A Dream of Wings: Americans and the Airplane, 1875-1905* (1981), and *Wings: A History of Aviation from Kites to the Space Age* (2003). His literary awards include the best book of the year prizes offered by both the American Institute of Aeronautics and Astronautics and the Aerospace Writers Association (1982, 1984); a Christopher Prize recognizing a work of literature "embodying the highest values of the human spirit" (1990); and the AIAA Gardner-Laser Prize for the best book on aerospace history selected from all books on the subject released in the last five years (2004). In 2001 the Wright State University conferred an honorary doctorate of humane letters on Dr. Crouch. President Clinton appointed Dr. Crouch Chairman of the First Flight Centennial Advisory Board. Reappointed by President George Bush, he continued to chair the board until the conclusion of the Centennial of Flight in 2003. He was only the third Smithsonian scholar to be named a Distinguished Lecturer by the Secretary of the Institution (2002).

Guillaume de Syon is a professor of history at Albright College and a history research associate at Franklin and Marshall College. He received his B.A. from George Washington University and received his Ph.D. from Boston University. He is the author of *Zeppelin: Germany and the Airship, 1900-1939* and of articles on the social and cultural history of technology.

M. Hill Goodspeed is historian and Head of Artifact Collections at the National Museum of Naval Aviation in Pensacola, Florida. He received his B.A. in history and journalism from Washington and Lee University, where he was a George C. Marshall Undergraduate Scholar, and holds an M.A. from the University of West Florida. In addition to servings as an adjunct professor of strategy and policy for the Naval War College in the College of Continuing Education, he is the author or editor of five books, including *U.S. Naval Aviation* (2001), named by the U.S. Naval Institute Proceedings as one of the notable naval books of 2001. His other works include *The Spirit of Naval Aviation* (1996), *U.S. Navy: A Complete History* (2003), *Skylines: American Cities Yesterday and Today* (2005), and *Skylines of the World: Yesterday and Today* (2006). He is also the author of twenty articles and book reviews that have been published in *The Journal of Military History, Proceedings, Naval History, Naval Aviation News, Wings of Fame, International Air Power Review, Foundation*, and *The Public Historian.* A third generation naval officer, he has made presentations at the Naval War College and the National Museum of the Pacific War, and appears frequently on History Channel programs.

Roger D. Launius is chair of the Division of Space History at the Smithsonian Institution's National Air and Space Museum in Washington, D.C. Between 1990 and 2002 he served as chief historian of the National Aeronautics and Space Administration. A graduate of Graceland College in Lamoni, Iowa, he received his Ph.D. from Louisiana State University, Baton Rouge, in 1982. He has written or edited more than twenty books on aerospace history, including *Space: A Journey to Our Future* (2004); *Space Stations: Base Camps to the Stars* (2003), which received the AIAA's history manuscript prize; *Flight: A Celebration of 100 Years in Art and Literature* (2003); *Reconsidering a Century of Flight* (2003); *To Reach the High Frontier: A History of U.S. Launch Vehicles* (2002); *Imagining Space: Achievements, Possibilities, Projections, 1950-2050* (2001); *Reconsidering Sputnik: Forty Years Since the Soviet Satellite* (2000); *Innovation and the Development of Flight* (1999); *Frontiers of Space Exploration* (1998, rev. ed. 2004); *Spaceflight and the Myth of Presidential Leadership* (1997); and *NASA: A History of the U.S. Civil Space Program* (1994, 2001).