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United States Government Accountability Office
Washington, DC 20548

March 14, 2005

The Honorable John Warner
Chairman
The Honorable Carl Levin
Ranking Minority Member
Committee on Armed Services
United States Senate

Subject: *Air Force Assessment of the Joint Strike Fighter's Aerial Refueling Method*

The Joint Strike Fighter (JSF) acquisition program is estimated to cost \$245 billion to develop and produce three variants of stealthy fighter aircraft—a conventional take-off and landing variant for the Air Force, an aircraft carrier variant for the Navy, and a short take-off and vertical landing variant for the Marine Corps and Air Force. A major goal of the JSF program is to reduce costs by maximizing commonality among variants. However, the Air Force conventional variant is being designed with a different aerial refueling method than those used by the two other JSF variants. U.S. fighters use two different methods for aerial refueling. Air Force fixed-wing aircraft are all currently fueled by a boom that extends from a tanker aircraft and is guided into a receptacle. The Navy and Marine Corps fighters use a probe that extends from the fighter to receive fuel when inserted into a drogue, which is a basket-like device on the end of a hose that extends from the tanker.

The Senate Armed Services Committee directed that we (1) examine the rationale behind the Air Force refueling decision for its JSF version, (2) determine the savings if the Air Force decided to change its refueling method on its JSF, and (3) determine the operational advantages or disadvantages if the Air Force decided to change its refueling method. This letter summarizes the information we provided committee staff on December 16, 2004.

To determine the Air Force rationale for selecting a refueling method that is different from the refueling method for the other variants, we reviewed JSF requirements documents, an evaluation by the JSF contractor of JSF refueling options, and design alternatives for each option. To assess the advantages and disadvantages of each method, we reviewed Air Force assessments of operational lessons learned and mishap reports for aerial refueling missions. To determine whether there were potential savings if the Air Force were to change its refueling, we reviewed an Air Force estimate of savings and the cost of impacts to other assets, such as tankers, to support this change. We also discussed relevant information with program officials from the joint JSF program office, the Air Combat Command, and the Air Mobility

Command. We conducted our review between August 2004 and January 2005 in accordance with generally accepted government auditing standards.

Summary

Revising the Air Force's conventional JSF aircraft refueling method from a boom to a probe and drogue would require modifying most of its current KC-135 tanker aircraft at an estimated cost of \$2.5-\$3.5 billion according to the Air Force. This estimated cost far outweighs the cost savings gained from having a common JSF refueling configuration estimated to be about \$180 million for the JSF program. However, the Air Force estimate of costs and savings does not consider the future tanker acquisition and potential cost savings if the Air Force JSF was refueled by the probe and drogue method. For example, a Rand Corporation study concluded that tanker requirements could be reduced from 17 percent to 50 percent depending upon specific warfighting scenarios if a tanker has the capability to refuel simultaneously two aircraft with the probe and drogue method. Using the current inventory of KC-135 tankers as a replacement baseline and a Congressional Budget Office¹ estimate of \$150 million for a new tanker, a 17-percent reduction in the number of tankers required could equate to an estimated savings of \$13.7 billion. The Air Force assessment of JSF refueling requirements did not fully address advantages and disadvantages of each method to make it clear whether a change is beneficial to DOD.

Background

The Air Force's tanker fleet of KC-10 and KC-135 aircraft provides the bulk of military aerial refueling services. These are large, long-range commercial aircraft modified into tankers. See figures 1 and 2.

¹Letter to the Honorable John McCain, United States Senate, May 7, 2002, from Dan L. Crippen, Director, Congressional Budget Office.

Figure 1: KC-135 refuels a flight of F-15 aircraft with a boom



Source: U.S. Air Force.

Figure 2: KC-10 refuels an F-18 with a probe and drogue



Source: U.S. Air Force.

Each KC-10 has a centerline boom and a drogue so that it can refuel any U.S. fixed wing aircraft. Further, 20 have been modified with drogue and hose on each wing that allows two fighters to simultaneously refuel—commonly called “multipoint.” While each KC-135 has a boom and can be configured with a drogue adaptor to refuel probe-equipped fighters, the configuration must take place on the ground before take-off. There are

currently only enough adapters to configure one-half the KC-135 fleet. The following table shows the refueling capability of the current Air Force tanker aircraft.

Table 1: Current U.S. Air Force Tanker Fleet and Refueling Capabilities

	KC-10 tanker	KC-135 tanker
Number in fleet	59	534
Capability	<ul style="list-style-type: none"> • All equipped with centerline boom and drogue refueling capability • 20 modified with wing air refueling pod system for multipoint drogue refueling capability 	<ul style="list-style-type: none"> • All equipped for centerline boom refueling • 20 modified with drogue multipoint refueling system • About half can be configured for centerline drogue refueling
Average age	22 years	44 years

Source: Air Force.

The Air Force is currently evaluating several alternatives including a new tanker to replace its aging KC-135 fleet. According to its mission need statement a new tanker should be equipped with a centerline boom and drogue capability so it can refuel both types of receiver aircraft on the same mission. Further, it should eventually be capable of refueling multiple aircraft simultaneously. The current and future tanker force capabilities are important factors in determining the type of refueling method selected for the JSF.

Evaluation Results

The Air Force plans to continue its reliance on boom refueling for its conventional take-off and landing JSF variant. The operational requirement document specified that this variant would use the standard Air Force refueling technique, which is the boom from its existing KC-10 and KC-135 tanker fleet. A JSF program official told us that during the requirements development process no evaluation was made on using a common refueling method and the requirement was driven by the existing and planned refueling assets for each service.

Adopting the probe and drogue method of refueling for the Air Force conventional take-off and landing JSF version is technically feasible and would save the JSF program about \$180 million according to an assessment made by the JSF contractor (Lockheed Martin). Of the total, an estimated \$176.2 million in production savings would accrue because the parts for a probe system are less expensive than a boom refueling system. However, the Air Force estimates it would cost between \$2.5 billion and \$3.5 billion to modify 415 KC-135 tankers to support a fleet of 1,763 Air Force JSF variants. The cost estimate is based on a budget estimate by Boeing Wichita, the KC-135 contractor, that the cost to add a multipoint refueling capability is \$6.1 million to \$8.4 million per tanker depending on the production lot size, 5 or 20 tanker aircraft. The Air Force used a simple ratio to estimate the number of tankers that would need modification. It assumed that 70 percent of its fighter force in 2020 would be JSFs. Therefore, 70 percent of its tanker force (415 tankers) should be capable of multipoint refueling.

In addition to the cost to modify the KC-135 tanker, Air Force officials stated that the boom method is less likely to damage the low observable feature of the JSF aircraft and, therefore, reduce its vulnerability to enemy air defenses. Thus, the chance for a successful mission is increased. In contrast to a stable boom, air turbulences are more likely to move the drogue basket and strike the JSF aircraft, leaving it more vulnerable to enemy air defenses because its low observable feature has been degraded. While the boom method has several operational advantages, a major disadvantage is its inability to simultaneously fuel two fighters with the multipoint capability provided with the probe and drogue method. The advantages and disadvantages associated with each method are shown in table 2.

Table 2: Analysis of Advantages and Disadvantages for Using Boom and Drogue Refueling Techniques on the Air Force JSF Variant

	Boom	Drogue
Advantages	<ul style="list-style-type: none"> • No modification of existing tankers for multipoint refueling or purchase of additional boom to drogue adapters • Less chance to damage to JSF low observable features • Weighs 4.1 pounds less than drogue assembly 	<ul style="list-style-type: none"> • Permits refueling by half the KC-135s and the British L1011 tanker • Permits multipoint refueling on 35 US tankers • Increased JSF variant commonality • Less time to refuel a 4-aircraft JSF flight • Avoids \$3.19 million in developmental cost • Improved allied interoperability • Saves \$180 million in JSF total cost • Could reduce number of new tankers
Disadvantages	<ul style="list-style-type: none"> • No refueling with British L1011 tanker • Loss of \$180 million in JSF production and operations and maintenance savings • No multipoint refueling • Less JSF variant commonality 	<ul style="list-style-type: none"> • Requires \$2.5-\$3.5 billion modification to KC-135s • Requires change in joint common specifications • Potential to damage JSF low observable features • Adds 4.1 pounds to aircraft weight • Drogue adapter requires preflight reconfiguration of KC-135 on the ground • Half of KC-135s cannot refuel with centerline drogue

Source: GAO analysis based on DOD data.

In assessing the options for refueling the JSF, Air Force Air Combat Command did not consider the potential for reducing the number of new tankers by using multipoint refueling. For example, Rand² identified three comprehensive studies³ that concluded that the use of multipoint refueling could reduce tanker requirements by 17 to 50 percent depending on a particular scenario. If new tankers with multipoint capability replace all KC-135 tankers, a 17-percent reduction would reduce the requirement by 91 aircraft (534 x .17 = 91). The Congressional Budget Office estimated that a new tanker would cost \$150 million. Thus, a 91-aircraft reduction would save an estimated \$13.7 billion. Additionally, the multipoint refueling offers improved operational efficiencies by refueling two aircraft at a time. However, quantifying the number of new tankers that could be reduced and the improved operational efficiencies would require a detailed study.

In its estimates of the number of KC-135s needed to be modified to support an Air Force probe and drogue version, the Air Force did not consider that some of the KC-135s would be replaced by the new tanker. By contrast, the JSF contractor, in estimating savings to the JSF program, projected that 170 new tankers may be in the inventory by the year 2020, which would reduce the number of KC-135s requiring modification. Quantifying this reduction, however, would require a detailed study. In addition, the Air Force did not consider the following factors in its projection.

- The Air Force recently delayed delivery of the first JSF aircraft by 1 year. Additional delays could occur in the JSF program given its early stage in the development process. If this happens, the Air Force would not need to modify as many KC-135s to support the JSF fleet.
- In December 2004, Air Combat Command officials told us that the Air Force is considering buying about 250 short takeoff and landing variant JSFs and about 1,300 conventional takeoff and landing JSFs. This would reduce the total number of Air Force JSFs to be acquired by 213 and could reduce the total number of tankers required to refuel the JSF fleet.

Also, the Air Force's belief regarding the adverse low observable effect caused by the drogue method lacked a technical engineering assessment on the likelihood and the extent of low observable damage, according to Air Combat Command officials. It also lacked an operational assessment to determine the impact on mission success caused by the damage.

Additional factors could also influence decisions about the refueling method for the Air Force variant of the JSF. First, as the JSF moves forward in development, the decision to change to a probe and drogue method will become more costly. Key points when the cost of design change increases include the critical design review scheduled in fiscal year 2006 and production scheduled to start in fiscal year 2007. Also, JSF quantities and delivery schedules could change as a result of the Quadrennial Defense Review in 2005.

² Bowie, C.J., et al., *Enhancing USAF Aerial Refueling Capabilities*, Santa Monica, Calif.: RAND, R-3801-AF, 1990 (for government use only; not available to the public).

³ Copeland, Donald, et al., *Multipoint Refueling Program Cost Benefit Analysis Final Report*, Santa Barbara, Calif.: Frontier Technology, Inc., 1995 (for government use only; not available to the public). George, William L., Lt. Col., USAF, *Utility of KC-135 Multipoint Modification*, Washington, D.C.: Air Force Studies and Analyses Agency, 1992 (for government use only; not available to the public).

Conclusions

The advantages and disadvantages of a decision to change the Air Force variant to the probe and drogue method of refueling can change based on a wider range of considerations than included in the Air Force's assessment. If the assessment includes only the JSF and other related legacy systems, it appears the cost to modify the 415 KC-135 aircraft at as much as \$3.5 billion is the overwhelming deciding factor and suggests that keeping the Air Force variant as a boom refueled aircraft is cost effective. However, if the assessment is expanded to include potential reductions in quantities of a new Air Force tanker because of efficiencies gained by multipoint refueling, it is not clear where the larger cost benefit to DOD lies.

Agency Comments and Our Evaluation

This correspondence is being issued without agency comments because DOD did not provide comments within the time allotted.

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Should you or your staff have any questions on matters discussed in this report, please contact me on (202) 512-4163 or Michael Hazard on 937-258-7917. Principal contributors to this report were Richard Strittmatter, Dayna Foster, Marie Ahearn, and Karen Sloan.



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