NASA'S INTEGRATED SPACE TRANSPORTATION PLAN AND ORBITAL SPACE PLAN PROGRAM

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE AND AERONAUTICS

COMMITTEE ON SCIENCE

HOUSE OF REPRESENTATIVES

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NASA'S INTEGRATED SPACE TRANSPORTATION PLAN AND ORBITAL SPACE PLANE PROGRAM

THURSDAY, MAY 8, 2003

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON SPACE AND AERONAUTICS,
COMMITTEE ON SCIENCE,
Washington, DC.

The Subcommittee met, pursuant to call, at 10:37 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Dana Rohrabacher [Chairman of the Subcommittee] presiding.

COMMITTEE ON SCIENCE
SUBCOMMITTEE ON SPACE AND AERONAUTICS
U.S. HOUSE OF REPRESENTATIVES
WASHINGTON, DC 20515

Hearing on

NASA's Integrated Space Transportation Plan and Orbital Space Plane Program
Thursday, May 8, 2003
10:30 p.m. – 12:30 p.m.
2318 Rayburn House Office Building

WITNESS LIST

The Honorable Frederick D. Gregory
Deputy Administrator
National Aeronautics and Space Administration

Dr. Jerry Grey
Director of Aerospace and Science Policy
American Institute of Aeronautics and Astronautics

The Honorable Dale D. Myers
President
Dale Myers and Associates

Dr. Michael D. Griffin
President and Chief Operating Officer
In-Q-Tel

HEARING CHARTER

SUBCOMMITTEE ON SPACE AND AERONAUTICS
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

NASA's Integrated Space Transportation Plan and Orbital Space Plane Program

THURSDAY, MAY 8, 2003
10:30 A.M.–12:30 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

PURPOSE

The Subcommittee on Space and Aeronautics will hold a hearing entitled *NASA's Integrated Space Transportation Plan and Orbital Space Plane Program* on Thursday, May 8th at 10:30 a.m. in 2318 Rayburn. The hearing will examine NASA's proposed Integrated Space Transportation Plan (ISTP)[1] and plans for the Orbital Space Plane (OSP). Topics will include the proposed ISTP architecture and OSP requirements, including NASA's development strategy for the OSP, plans for risk reduction and technology demonstrations, as well as the proposed schedule and total cost of the OSP program.

BACKGROUND

Since the 1980s, NASA has struggled to develop a new launch system to provide safe, routine, and less expensive access to space. Over the years, numerous concepts have been studied, but few have made it beyond concept definition and none have flown in space. In March 2001, NASA canceled the X–33 single-stage-to-orbit program and the X–34 technology demonstrator after spending $1.4 billion (not including $356 million spent by Lockheed on X–33). NASA concluded that the technical barriers of the X–33 were too great and that the benefits of the X–34 did not justify the cost. Last year, NASA canceled the X–38, a prototype of a Crew Return Vehicle (CRV), because it was believed that a multi-purpose vehicle would be a better use of its resources. NASA headquarters estimated costs for an X–38 vehicle and three production CRVs in the range of $3 billion to $5 billion.[2] NASA is continuing to move forward with the X–37 flight demonstration as part of the OSP program, but its value and relevance as a technology demonstrator for the OSP program is questionable because the on-orbit demonstration would not occur until after NASA made its decision for full-scale development.

Last November, NASA submitted a budget amendment to its FY 2003 request to restructure and refocus the ISTP. The budget amendment proposed to extend the life of the Space Shuttle by creating a Service Life Extension Program (SLEP), to establish a program to develop an OSP for crew rescue and crew transportation to Space Station, and to establish a technology program called the Next Generation Launch Technology (NGLT) program. The budget amendment bolstered reserves on the Space Station program, as recommended by the Young Commission.

Because the budget amendment was submitted late in the 107th Congress and because no hearings were held to review the proposal, Congress specifically stated in the Omnibus appropriations report that the "funding level is not endorsed or denied," but wanted to examine the details of the proposal, especially cost. The Omnibus bill did provide funding for the OSP at the requested level of $296 million for FY 2003.[3] Other than minor changes, NASA's FY 2004 budget request reflects the program proposed in the budget amendment. This is the first hearing held by any committee on NASA's ISTP and OSP plans.

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[1] The Integrated Space Transportation Plan (ISTP) consists of three elements: (1) The Space Shuttle; (2) The Orbital Space Plane (OSP); and (3) Next Generation Launch Technologies (NGLT). See chart in the Appendix.
[2] NASA, CRV acquisition cost estimate, November 2002
[3] P.L. 108–7, H.Rpt. 108–10

Current Status of OSP

In January 2003, NASA finalized the OSP top-level requirements, known as the Level 1 requirements. NASA divided these requirements into two parts: (1) the requirements for the crew rescue capability with a delivery date of 2010 (although the need date is 2006 because the Russians complete their obligations for Soyuz crew return capsules); and (2) the requirements for the crew transportation capability to ISS and back with a delivery date of 2012. The complete Level 1 requirements are provided in Appendix 3.

NASA recently awarded three study contracts totaling $135 million: $45 million each to Lockheed Martin, Boeing, and the Northrop Grumman/Orbital Sciences team. NASA expects the contractors to perform technical engineering studies and further refine the requirements. NASA will hold a System Requirements Review in November 2003 and expects to make a decision on full-scale development by the end of 2004. Key technical tradeoffs include: (1) one vehicle or a family of vehicles; (2) a winged vehicle, lifting body, or capsule and; (3) entirely reusable, partially reusable, or expendable. The results of these tradeoffs will have a significant impact on cost and schedule.

Apollo-style OSP Study

At the urging of several NASA Advisory Council (NAC) members, most notably former Senator John Glenn, NASA enlisted a small group of distinguished aerospace executives and system experts to assess the viability of using Apollo designs as a jump-start toward satisfying the OSP Level 1 requirements. Mr. Dale Myers, a former Deputy NASA Administrator and experienced manager from Apollo and Shuttle, was a member of the Apollo OSP study team and will be a witness at the hearing to present the findings of the team.

In short, the team unanimously concluded that an Apollo-derived crew rescue vehicle, with a four to six person crew, appears to have the potential of meeting most of the OSP level 1 requirements for crew rescue, with the possible exception being the requirement to transport an injured astronaut to definitive medical care within 24 hours. An Apollo derived crew transfer vehicle would also appear able to meet most of the OSP Level 1 requirements for crew transfer with the addition of a service module for propulsion to rendezvous with the Space Station. The study team concluded that the idea had sufficient merit to warrant a serious detailed study of the performance, cost, and schedule for this approach as compared with other OSP options. NASA does not plan to investigate the Apollo concept further, but is providing the study results to the contractors for their consideration.

OSP Schedule Acceleration Study

In addition to the Apollo study, NASA convened several in-house and contractor teams to assess whether it was possible to accelerate the schedule for the OSP. While the teams found limited potential for accelerating the schedule, up to possibly two years, they agreed on several common themes, specifically to rely heavily on existing technology, narrow the design options early, set requirements and do not change them, allow sufficient budget reserves to manage risk, and consider using a single vehicle design for both the crew rescue and crew transfer functions. NASA plans to incorporate the results of these studies into a revised (post-Columbia) Integrated Space Transportation Plan, due to be completed this summer.

KEY ISSUES

Vision for the Future?

NASA has yet to determine its goals for human spaceflight beyond Space Station. Without long-term goals, it is very difficult to know how best to invest funds in developing a new space transportation system, and the agency runs the risk of repeating the mistakes of the past by building the system first and then deciding how they want to use it later. While the ISTP is intended to fill a specific need for the Space Station, such a large and long-term investment should be made in the context of the agency's long-term goals. A clear set of goals would provide the proper framework for making policy decisions and setting funding priorities.

Do We Need and Can We Afford Both Shuttle and OSP?

NASA defines the OSP as a "supplement" to the Space Shuttle, and in briefings to staff, NASA has asserted that the Space Shuttle is required for the duration of the International Space Station (ISS) program with or without OSP. However, NASA has not substantially supported this argument. The ISTP plan calls for the Space Shuttle to continue to operate at least until 2015 and possibly beyond 2020. While plans for the Space Shuttle will certainly be examined again after the *Columbia* Accident Investigation Board reports, NASA has not made a compelling argument that it needs both the Shuttle and an OSP, nor that it can afford building and maintaining both systems. In addition, it is unclear to what degree NASA considered capabilities from the International Partners, such as Russian Soyuz capsules and Progress vehicles and the European Automated Transfer Vehicle (ATV), in deciding what capabilities the U.S. must develop.

How do Tech Demos Fit into OSP?

NASA proposes to spend approximately $750 million on technology demonstrations between 2003 and 2006. The projected budget for each of the three demonstration projects is provided in the Appendix. Major demonstrations include the X–37 space flight demonstrator, the Pad Abort Demonstration (PAD) to demonstrate crew abort concepts on the launch pad, and the Demonstration of Autonomous Rendezvous Technology (DART). All of these technology demonstrations were started prior to the OSP program and, therefore, were not necessarily driven by the needs of the OSP program. Since the OSP program has not yet progressed beyond establishing the Level 1 requirements, it is not clear that these are the highest priority technologies to demonstrate and warrant the proposed $750 million investment.

What will OSP Cost?

NASA proposes to spend more than $4 billion on the OSP (including the technology demonstrations) between FY 2003 and FY 2008, but does not plan to field the crew rescue capability until 2010 and the crew transportation capability until 2012. NASA has not provided an estimate for the cost to achieve each of these milestones or an estimate for the total cost of the program. Clearly, this is critical information for making any policy decision. NASA managers unofficially estimate the total cost to be in the range of $9 to $13 billion, however this figure could grow dramatically and will be driven primarily by the complexity of the selected concept and the amount of research and development NASA chooses to take on with the development of the OSP. Without a solid cost estimate the committee must decide whether it has enough confidence in the plan to justify the $550 million requested for FY 2004.

Why did NASA Cancel Alternate Access to Station?

NASA proposes to eliminate the Alternate Access to Station (AAS) program later this year despite the fact that the House Appropriations Committee reported out strong language directing NASA to spend $62.7 million in FY 2003 on AAS to "demonstrate a near-term commercial ISS re-supply service." NASA's decision to cancel AAS appears particularly short-sighted since the Space Station's crew size is now reduced from three to two because of the limited ability to deliver enough water, food, and other supplies to support more than a two person crew while the Shuttle is grounded. NASA's FY 2004 budget request does not include the projected run-out of $85 million for AAS included in the FY 2003 request. Some in industry have highlighted that an architecture consisting of OSP and an Alternate Access capability for cargo delivery would obviate the need for the Space Shuttle entirely.

Why did NASA Cancel the X–38 Crew Return Vehicle Prototype?

Before NASA changed its program and submitted the budget amendment last November, NASA had an objective to provide a Crew Transfer Vehicle (CTV) capability by 2012. NASA was pursuing a CRV prototype known as the X–38 program. The X–38 performed several approach and landing demonstrations and could have provided an interim crew return capability for the ISS by 2006, but was canceled. On June 13, 2002, NASA notified Congress of the project's cancellation citing their desire to pursue a multipurpose vehicle, which could include both crew transport and crew return capabilities as a more optimal use of NASA's resources than pursuit of a single-purpose vehicle, such as the X–38 project. After 2006 the Russians are not required to provide any more Soyuz capsules and the U.S. is prohibited from purchasing Russian hardware because of the restrictions on doing so in the Iran Non-Proliferation Act of 2000. A key issue is whether NASA should re-examine its decision to cancel the X–38.

Are Expendable Launch Vehicles Acceptable for OSP?

The OSP will be launched on an Expendable Launch Vehicle (ELV), such as an Atlas or Delta rocket. ELVs were used for the Mercury, Gemini, and Apollo programs in the 1960s, however none of these programs had a winged vehicle on top of the rocket as may be (but not necessarily) proposed on the OSP program. A key issue is whether the use of ELVs poses an unacceptable risk for launching humans into orbit. In addition, today's ELVs cost approximately $150 million each, so the cost of the launch vehicle combined with the cost of an OSP (amortized if it is reusable) could approach the cost per flight of the Shuttle, arguably in the neighborhood of $500 million.

WITNESSES

The Honorable Frederick D. Gregory is the Deputy Administrator of NASA. He serves as the Chief Operating Officer for the agency and reports directly to NASA's Administrator. Prior to his Senate confirmation in August 2002, Mr. Gregory served as Associate Administrator for Space Flight, and for nine years as the Associate Administrator, Office of Safety and Mission Assurance. Mr. Gregory has logged over 455 hours in space as an astronaut, and has extensive experience as a test pilot, and manager of flight safety programs and launch support operations.

Dr. Jerry Grey is the Director of Aerospace and Science Policy for AIAA, a member of the Science Counsel of the NASA Institute for Advanced Concepts, and Visiting Professor of Mechanical and Aerospace Engineering at Princeton University. Dr. Grey has served as consultant to the U.S. Congress as Chairman of the Office of Technology Assessment's Solar Advisory Panel and several space advisory panels, and as a member of the NASA Advisory Council, and Vice-chairman of the Commercial Space Transportation Advisory Committee.

The Honorable Dale D. Myers is the President of Dale Myers and Associates, and has had a distinguished career in high-level management positions in government and industry. Mr. Myers has served as NASA's Deputy Administrator, and Associate Administrator for Manned Space Flight; as Under Secretary of the U.S. Department of Energy; as Vice President and Program Manager of the Space Shuttle Program for Rockwell International; and prior to that as Vice President and Program Manager of the Apollo Command and Service Module for North American Rockwell. In March of this year he led a team of experts tasked to assess the viability of using Apollo heritage designs to satisfy the OSP requirements.

Dr. Michael Griffin is the President and Chief Operating Officer of In-Q-Tel. He has nearly 30 years of experience managing information and space technology organizations. Dr. Griffin has served as Executive Vice President and CEO of Magellan Systems Division of Orbital Sciences Corporation, and as EVP and General Manager of Orbital's Space Systems Group. Prior to that he served as both the Chief Engineer and Associate Administrator for Exploration at NASA, and at the Pentagon as the Deputy for Technology of the Strategic Defense Initiative Organization.

Appendix 1

The table below summarizes the assumptions NASA has used when making space transportation strategy decisions over the past decade, how they have changed, and how they are now forecast in the revised ISTP.[4]

Assumptions	SSTO FY1994	SLI / ISTP FY1999	New ISTP Forecast
Single-Stage-to-Orbit (SSTO)	Achievable	Too Risky, go Two-Stage	Too Risky, go Two-Stage
Near-Term Launch Market	Rapid growth	Stable, little growth	Declining
RLV Costs	~ $4-6 billion	~ $10 billion	> $20 billion
Gov't Share of Development Costs	Little	Most	All
Market Drivers	Commercial	Commercial Convergence	Space Station Focused

NASA studied the following options during the summer of 2002 during the development of the current ISTP:

- Baseline ISTP—Make the decision in 2006 to build a new RLV two-stage booster and crew transfer vehicle to deliver crew and some cargo.
- Orbital Space Plane and delay RLV booster—Develop an Orbital Space Plane by 2010–12 to be flown atop an existing Evolved Expendable Launch Vehicle (EELV) that must be human rated.
- Develop a Prototype RLV Booster by about 2011—Build a common RLV prototype booster with the Department of Defense. An operational booster would come later.
- Breakthrough Technology—Continue to spend money on long-term, high payoff technology like hypersonic propulsion placing RLV on hold indefinitely.

NASA has decided to pursue the second option—Orbital Space Plane and delay RLV booster. In the budget amendment submitted to Congress in November 2002, NASA redirected the SLI program. SLI funds were transferred to the Orbital Space Plane program, as well as the Space Shuttle, space station, and Next Generation Launch Technology (NGLT) program.

[4] NASA, Justification for FY 2003 Budget Amendment, pg. 5.

Appendix 2

The following tables summarize 1) The changes to the Space Launch Initiative as a result of NASA's budget amendment in November 2002, and 2) NASA's FY04 budget request for the Orbital Space Plane program.

Restructured Space Launch Initiative ($'s in millions) – November '02 Budget Amendment

SPACE LAUNCH INITATIVE	FY 03	FY 04	FY 05	FY 06	FY 07	TOTAL
February FY 03 Budget	759	1003	1056	1256	1348	5422
Systems Architecture Definition	64	43	43	43		192
RLV Risk Reduction	502	750	580	785	866	3482
NASA Unique Systems	131	130	390	390	482	1523
Alternative Access	63	81	43	38		225
Changes	120	-85	-128	-224	-274	-590
Add to NASA Unique (Orbital Space Plane)	165	312	42	145	218	882
Reduce remaining SLI	-165	-532	-305	-504	-627	-2133
Transfer 3rd Generation into SLI	120	135	135	135	135	661
Amended FY 03 Budget *	879	919	928	1031	1074	4832
Orbital Space Plane †	296	442	432	535	700	2405
Next Generation Launch Technology	584	477	496	496	374	2427

* H.Rpt.108-10 called for a decrease of $40 million to the Space Launch Initiative program[7], and stated, "The conferees have taken this action without prejudice. The conferees note that the Congress received a budget amendment on November 7, 2002, which restructured the Space Launch Initiative with the goal of developing an Orbital Space Plane with ISS crew return capability by 2010."

† H.Rpt.108-10 also stated, "Fiscal year 2003 funding for the Orbital Space Plane was set at $296 million in the budget amendment. This funding level is not endorsed or denied by the conferees and is therefore subject to change by NASA as it formulates its operating plan for fiscal year 2003. The conferees look forward to working with NASA during the review of the fiscal year 2004 budget request to learn more precisely the elements that comprise the cost estimates NASA has provided in the budget agreement and other documents submitted to the Committee on Appropriations of the House and Senate.

NASA's FY04 Orbital Space Plane Program request ($'s in Millions)

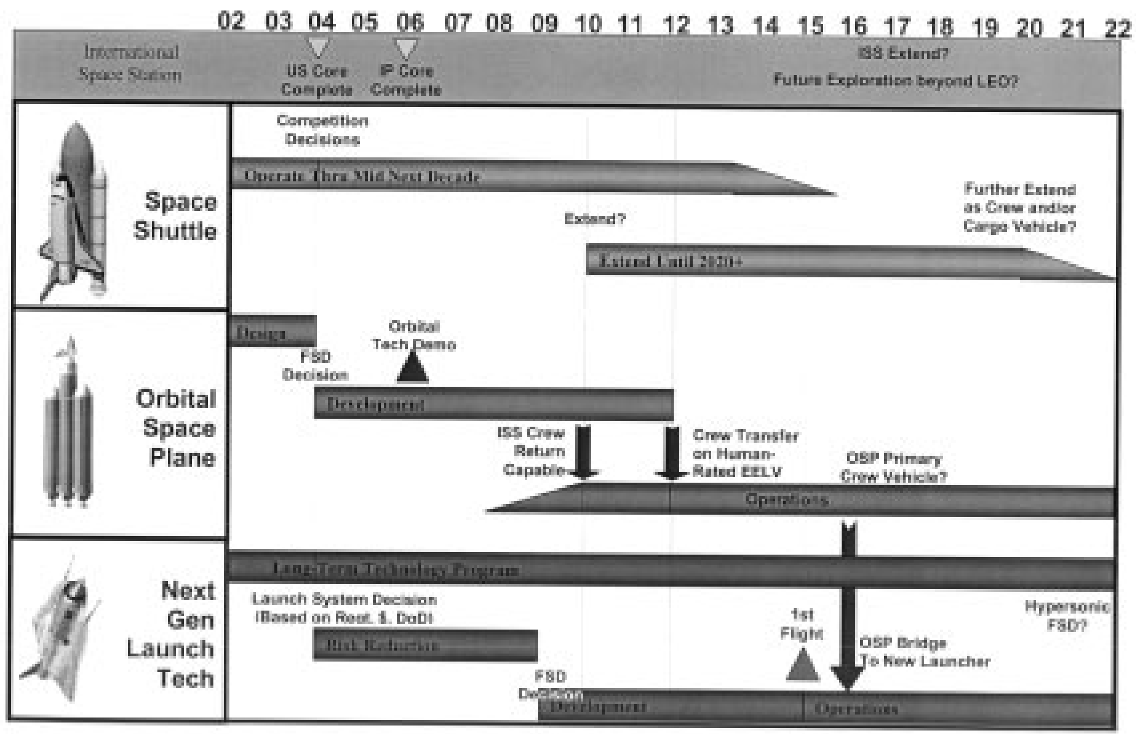
Orbital Space Plane Program	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08	Total FY 03-08
Technology & Demonstrations	285.7	226.0	186.4	87.1			785.2
X-37	230.4	178.0	165.2	73.7			647.3
DART	25.5	18.0					43.5
PAD	29.8	30.0	21.2	13.4			94.4
Design Development & Production	97.6	324.1	423.5	629.5	894.7	916.0	3285.4
Orbital Space Plane Total	383.3	550.1	609.9	716.6	894.7	916.0	4070.6

Note: All estimates are full-cost[8]

[7] H.Rpt.108-10 is the Conference Report to the FY2003 Omnibus Appropriation (P.L.108-7)

[8] Care should be taken when comparing amounts shown in the two tables. Amounts in the first table are not full-cost. Those in the second table are full-cost. All the figures were provided by NASA. NASA has not provided the appropriate full-cost conversions. Congress appropriated funding for FY 2003 based on the FY 2003 categories, with no full-cost accounting.

Integrated Space Transportation Plan (ISTP)



Appendix 3

Orbital Space Plane Program Level 1 Requirements

1. The system, which may include multiple vehicles, shall provide rescue capability for no fewer than four ISS crew as soon a practical but no later than 2010.
2. The system shall provide rescue capability that allows the safe return of deconditioned, ill or injured crew members with ongoing treatment until arrival at definitive medical care within 24 hours. Crew should not require suits in the vehicle, but the vehicle should support crew wearing suits if the situation warrants.
3. The system for rescue shall provide for rapid separation from the ISS under emergency conditions followed by return to Earth.
4. Safety requirements—system for crew rescue:
    a. The availability (defined as "a full-up vehicle able to perform it's mission") for the escape mission shall be at least:
        i. Objective: 99%
        ii. Minimum Threshold: 95%
    b. The risk of loss of crew shall be, with high confidence, lower than the Soyuz for the rescue mission.
5. The system shall provide transportation capability for no fewer than four crew, to and from the ISS as soon a practical, but no later than 2012.
6. Safety requirement—system for crew transport: The risk of loss of crew shall be, with high confidence, lower than the Space Shuttle for the transport mission.
7. The system shall be designed for minimum life cycle cost.
8. The system shall meet all applicable ISS requirements for visiting and attached vehicles.
9. Compared to the Space Shuttle, the system shall require less time to prepare and execute a mission and have increased launch probability.
10. Compared to the Space Shuttle, the system shall have increased on-orbit maneuverability.

Orbital Space Plane Program Concept of Operations

1. The vehicle(s) shall initially launch on an ELV.
2. The system shall be operated through at least 2020. However, the system should be designed so that I could be operated for a longer time.
3. NASA envisions that the systems for crew rescue and crew transport could be different versions of the same vehicle design.
4. The system shall provide contingency capability for cargo delivery to or from the ISS to support a minimal level of science.
5. The system shall support a nominal ISS crew rotation period of 4–6 months.

Chairman ROHRABACHER. Okay. I hereby call this meeting of the Space and Aeronautic Subcommittee to order. And without objection, the Chair will be granted authority to recess this committee at any time. All right. Hearing no objection.

At today's hearing, we will examine NASA's Revised Integrated Space Transportation Plan and the Orbital Space Plane. Given NASA's poor track record on space transportation programs, like NASP, X–33, X–34, and more recently, SLI, and I think I supported every one of those programs, the American people have seen little in return from the investment in these programs, unless—of course, I am always willing to be corrected when I say something like that. And so we see very little in return in terms of improving our nation's launch capabilities. And in light of these failures, or at least non-successes, I welcoming—I am welcoming the restructuring of the Space Launch Initiative as a positive step toward making good on the promise of cheap, reliable, and safe access to space.

As we begin to peel back the layers of the onion, however, and NASA's proposed plan appears to be, perhaps, just another initiative that is long on promises and short on likely results. So let us hear about it. That simply won't cut it any more, and we have seen this in the past, so let us discuss this and make sure that is not going to happen.

In the wake of the *Columbia* tragedy, NASA continues to view its space transportation requirements through a Space Shuttle prism. For example, for the foreseeable future, NASA has only one U.S.-controlled option for delivering cargo to the International Space Station, and that is the Space Shuttle.

Just last weekend, we reduced the space station's crew from three to two, because NASA can not deliver enough water and food to keep three people alive. Furthermore, we are now completely dependent on our European and Russian partners to deliver enough supplies to maintain even this reduced crew. Unbelievably, NASA is sticking by their plan to kill the Alternative Access to the Station program even when they are in the middle of—in a situation like this. And they are hoping that the Shuttle's return to flight will solve this problem. Now that is, of course, until the next crisis happens.

Something doesn't make sense here. It just doesn't make sense. And that is what we want to find out today. Let us try to make sense of this strategy. So further, let me note that NASA views the Orbital Space Plane as merely a supplement to Shuttle, at least that is what it appears. And it is unclear how NASA will pay to develop the Orbital Space Plane while operating the Shuttle, which we all know is a costly transportation system, let alone whether NASA can afford to operate both the Orbital Space Plane and the Shuttle at the same time.

Additionally, NASA has yet to provide a clear picture regarding the strategy, schedule, and cost of the Orbital Space Plane. And let me add that over the years, I have been supporting research projects both in NASA and in the Air Force and in the DOD side and NASA side that I would've expected something, at least a schedule, that we could accept at this moment from all of the money that has been put into that research. So we need to discuss these things.

Some of us see the Orbital Space Plane and alternative cargo delivery capability as a potential path for an early phase-out of the Space Shuttle that in order to save lives and money while maximizing the research potential of the Space Station. But—and considering the *Challenger*'s and the *Columbia*'s situation and the disasters we have had there, than maybe this makes sense. But NASA has proposed a plan that offers little hope in this regard. Apparently NASA's space transportation strategy continues to be all things to all people, and we have got to pin that down today.

I have discussed these issues with well-informed individuals. I had a personal discussion with Senator John Glenn, and I believe, as many of these other experts believe, that NASA must give greater consideration to finding a viable near-term solution for our immediate space access challenges. NASA should not be spending huge sums of money on an uncertain Orbital Space Plane design, and we shouldn't be depending exclusively on foreign partners for ISS re-supply. So as Sean O'Keefe would say, "Hope is not a strategy. We need a clear and realistic plan that sets priorities and delivers results." That is what happens when you testify. Sometimes you get quoted back to yourself.

Post-Columbia realities demand that we reject a business-as-usual approach. Today's distinguished panel will help us focus our attention on the barriers to achieving safe, reliable, and affordable access to space.

[The prepared statement of Mr. Rohrabacher follows:]

PREPARED STATEMENT OF CHAIRMAN DANA ROHRABACHER

Today's hearing will examine NASA's revised Integrated Space Transportation Plan and the Orbital Space Plane. Given NASA's poor track record on space transportation programs like NASP, X–33, X–34, and more recently SLI, the American people have seen little return from their investment in improving our nation's launch capabilities. In light of these failures, I welcomed the restructuring of the Space Launch Initiative as a positive step towards making good on the promise of cheap, reliable, and safe access to space. As we begin to peel back the layers, however, NASA's proposed plan appears to be just another initiative that is long on promises and short on likely results. That simply won't cut it any more with this subcommittee.

Even in the wake of the *Columbia* tragedy, NASA continues to view its space transportation requirements through a Space Shuttle prism. For example, for the foreseeable future, NASA has only one U.S.-controlled option for delivering cargo to the ISS, and that is the Space Shuttle. Just last weekend we reduced the Space Station's crew size from three astronauts to two because NASA cannot deliver enough water and food to keep three people alive. Furthermore, we're now completely dependent on our European and Russian partners to deliver enough supplies to maintain even this reduced crew. Unbelievably, NASA is sticking by their plan to kill the Alternate Access to Station program, and hoping that the Shuttle's return to flight will solve this problem. . .that is until the next crisis.

Further, NASA views the Orbital Space Plane as merely a supplement to the Shuttle. But it is unclear how NASA will pay to develop the Orbital Space Plane while operating the Shuttle, let alone whether NASA can afford to operate both the Orbital Space Plane and Shuttle at the same time. Additionally, NASA has yet to provide a clear picture regarding the strategy, schedule, and costs for the Orbital Space Plane.

Some of us see the Orbital Space Plane and alternative cargo delivery capability as a potential path for early phase-out of the Space Shuttle in order to save lives and money while maximizing the research potential of the Space Station. But NASA's proposed plan offers little hope in this regard. Apparently, NASA's space transportation strategy continues to be all things to all people.

I've discussed these issues with well-informed individuals like former Senator John Glenn, and I believe, as they do, that NASA must give greater consideration to finding viable, near-term solutions for our immediate space access challenges. NASA should not be spending large sums of money on an uncertain Orbital Space Plane design. We shouldn't be depending exclusively on foreign partners for ISS resupply. As Sean O'Keefe would say: Hope is not a strategy. We need a clear and realistic plan that sets priorities and delivers results.

Post-Columbia realities demand that we reject a business as usual approach. Today's distinguished panel will help us focus our attention on the barriers to achieving safe, reliable, and affordable access to space.

Chairman ROHRABACHER. And I would now like to see if Mr. Gordon, as our—would like to show us, perhaps—now just a note that Mr. Gordon has been declared, officially now, the fastest member of the United States Congress and—because he has won a marathon, something that—I challenged him to a surf contest. He would not go along with that. So he won the marathon, and now we are going to see just how fast he can be.

Mr. GORDON. Well, you want me to get my remarks over with quickly, is that it, Mr. Chairman? Probably the quickest thing I could do is say amen to your earlier remarks. I think you were right on line.

Good morning, everyone. I would like to welcome the witnesses to today's hearing. I believe this hearing will be one of the most important that the Subcommittee will hold this year. Last November, NASA proposed yet another redirection of its space transportation program. And it proposed to start up a new multi-billion dollar Orbital Space Plane project with price tags still to be determined. Those proposals would merit serious congressional scrutiny, even in ordinary times, but these are not ordinary times.

In the aftermath of the *Columbia* accident, both Congress and this Administration are going to have to make some tough decisions about NASA's programs and priorities. While I think we can not really make informed decisions about the Space Shuttle and the Orbital Space Plane until we hear from the Gehman Board later this year, we can start reviewing our options. I hope that this hearing will help us to gather some of the information that we need.

When NASA announced last November that it wanted to build an Orbital Space Plane, I was skeptical, but willing to listen. I still am. It seems to me that NASA has given us a solution, the Orbital Space Plane, but it hasn't yet given us a credible story on what the problem is that we are trying to address. For example, the Administration canceled the Space Station Crew Return Vehicle Program in 2001 in order to save money on the Space Station program. At the time, Congress was told that the CRV fleet would have cost about $1.3 billion, a figure supported by the Tom Young Task Force and that the first vehicle could not have been ready—or could not be ready—or could have been ready as early as 2006. That was good, because the Shuttle—or rather the Russian commitment to supply Soyuz CRVs expired also in 2006.

Now we are told that NASA wants to build the Orbital Space Plane so it can serve as the space station's CRV, but it won't be ready as a CRV until 2010, at best, and even a couple years later for full capabilities, four years after it is needed. And NASA still—and NASA will spend at least $4 billion on it over the next five years, and perhaps two or three times more than that before the OSP project is through.

That doesn't sound like saving money to me. Instead, it looks like NASA is trying to balance the Space Station books over the short-term by shifting the costs of the CRV out into the future and making those costs a lot bigger than they otherwise would be.

NASA has also said they want to build the OSP to supplement but not replace the Space Station—or the Space Shuttle for crew transfer to and from Space Station, but not until another decade has past. Well, that is the answer to a question that we are not asking. Among the questions that we do need to ask—that we do need answered are the following: will we have to phase-out the Space Shuttle in the near future or can, and should we—should it be flown for another 20 years; if a decision is made to phase-out the Shuttle, what space transportation system should be built that will best support the Space Station over the operational lifetime; and what space transportation system will best support NASA's future space exploration goals?

I think that the burden of proof has to be on NASA to convince us that its latest space transportation plan addresses these important questions.

Well, we have a lot to talk about today, so again, I welcome our witnesses and look forward to your testimony.

[The prepared statement of Mr. Gordon follows:]

PREPARED STATEMENT OF REPRESENTATIVE BART GORDON

Good morning. I'd like to welcome all of the witnesses to today's hearing. I believe that this hearing will be one of the most important that the Subcommittee will hold this year.

Last November, NASA proposed yet another redirection of its space transportation program. And it proposed to start up a new, multi-billion dollar Orbital Space Plane project—with a price tag that is still "TBD." Those proposals would merit serious Congressional scrutiny even in ordinary times. But these aren't ordinary times.

In the aftermath of the *Columbia* accident, both Congress and this Administration are going to have to make some tough decisions about NASA's programs and priorities. While I think we can't really make informed decisions about the Space Shuttle and the Orbital Space Plane until we hear from the Gehman Board later this year, we can start reviewing our options.

I hope that this hearing will help us gather some of the information we will need. When NASA announced last November that it wanted to build an Orbital Space Plane, I was skeptical, but willing to listen. I still am.

It seems to me that NASA has given us a solution—the Orbital Space Plane—but it hasn't yet given us a credible story on what the problem is that they are trying to address. For example, the Administration canceled the Space Station's Crew Return Vehicle program in 2001 in order to save money on the Space Station program. At the time, Congress was told that the CRV fleet would have cost about $1.3 billion—a figure supported by the Tom Young Task Force—and that the first vehicle could have been ready as early as 2006. That was good, because the Russian commitment to supply Soyuz CRVs expires in 2006. *Now* we are told that NASA wants to build the Orbital Space Plane is so *it* can serve as the Space Station's CRV.. . .But it won't be ready until 2010—four years after it is needed. . .and NASA will spend *at least* $4 billion on it over the next five years—and perhaps *two to three times more than that* before the OSP project is through.

That doesn't sound like saving money to me. Instead it looks as though NASA is trying to balance the Space Station books over the short-term by shifting the costs of the CRV out into the future—and making those costs a lot bigger than they otherwise would have been. That's not my idea of good financial management.

NASA has also said that they want to build the OSP to supplement—but not replace—the Space Shuttle for crew transfer to and from the Space Station, but not until another decade has passed. Well, that's the answer to a question we're not asking.. . . Among the questions that we *do* need answered are the following:

- Will we have to phase out the Space Shuttle in the near future, or *can* and *should* it be flown for another 20 years?
- If a decision is made to phase out the Shuttle, what space transportation system should we build that will best support the Space Station over its operational lifetime?
- And what space transportation system will best support NASA's future space exploration goals?

I think that the burden of proof has to be on NASA to convince us that its latest space transportation plan addresses those important questions.

Chairman ROHRABACHER. Thank you very much for that very provocative statement and again, you have made some points that are really important. Without objection, the opening statement of all of the Members will be put into the written record so we can get right to the testimony. And hearing no objection, so ordered. I would also ask unanimous consent to insert at the appropriate place in the record the background memorandum prepared by the majority staff at this hearing. Hearing no objection, so ordered.

[The prepared statement of Mr. Feeney follows:]

PREPARED STATEMENT OF REPRESENTATIVE TOM FEENEY

The loss of *Columbia* has prompted a worthwhile discussion about how to pursue a rigorous but sustainable strategy for manned space flight and exploration. In particular, NASA must look beyond its reliance on a single, complex vehicle for space access. Accordingly, in its strategic plan issued before February 1, 2003, NASA proposed an Integrated Space Transportation Plan.

So far so good. But the devil is in the details, which remain sketchy at best. Congress can't fund an Integrated Space Transportation Plan unless it receives a measured, detailed, and well-conceived plan. Broad concepts won't suffice.

Furthermore, NASA has a legacy of delivering paper and PowerPoint presentations and not operational vehicles. In the private sector, a business must eventually deliver a tangible good or service. Similar accountability must apply to the public sector. In its quest to place Americans on the moon, NASA consistently delivered and flew Mercury, Gemini, and Apollo vehicles. NASA needs to repeat this legacy of accomplishment that goes beyond keeping paper mills operating at capacity.

This paucity of details and NASA's track record of undelivered promises provides fuel for considerable frustration. So today's hearing will probably feature a free and candid discussion. Although I will politely disagree with some of the expressed sentiments, I also note that this subcommittee is united in our strong desire and support for a vigorous manned space program.

The Space Shuttle provides the only near-term means to transport the segments and personnel needed to complete construction of the International Space Station and then the supplies, equipment, and personnel needed to fully utilize the completed station. Thus, NASA must promptly yet prudently return the Shuttle to flight.

But simultaneously, NASA must flesh out the details behind its Integrated Space Transportation Plan and then get to the business of delivering an operational vehicle as expeditiously as possible.

[The prepared statement of Ms. Jackson Lee follows:]

PREPARED STATEMENT OF REPRESENTATIVE SHEILA JACKSON LEE

Mr. Chairman,

Thank you for calling this hearing, which is a needed follow-up to our interactions with NASA and Administrator O'Keefe last Congress. I am glad to see some fresh faces before us today. My statement and my questions will likely be almost identical to those I have been making for years. I hope that we will start getting some more insightful answers about the mission and vision of NASA for the 21st Century, and beyond.

I would like to thank our panel of experts for taking the time to come share their ideas with us. I would like to offer a special welcome to Deputy Administrator Frederick Gregory, confirmed in August of last year. Mr. Gregory, I am sure that with your vast experience as an astronaut and in service on Safety and Mission Assurance issues, you will be a great asset to the NASA leadership. I look forward to hearing your personal views on the future of the NASA mission.

I think everyone here knows my passion for NASA and all of the exciting work they do. NASA plays many roles, and means so much to America today. NASA is a source of dreams for our young and old alike. It provides insights into the origins and destiny, and wonder, of our universe. On the way to this noble goal, NASA develops innovations that spur on our economy and keep us on the cutting edge of technology. NASA inspires young engineers and scientists to push their minds to new levels of excellence.

The tragedy aboard the Space Shuttle *Columbia* has hit this entire nation hard—especially those of us from Houston, the home of Johnson Space Center, and us here in the Science Committee who have made Space exploration such a part of our own lives. I think we all feel that NASA is truly an integral part of the future of the United States. We are being patient, as Admiral Gehman and the C.A.I.B. are doing the painstaking and meticulous work of unraveling the mystery of the *Columbia* disaster; however, I am also looking forward to seeing NASA moving forward—soon.

That is exactly why I am deeply troubled by the direction this important program in taking. I do not want to see NASA become an exhibit in museums and history books, instead of being the leader in technology and exploration that it should be. At NASA recently, there seems to be a fundamental disconnect between logic and policy. I feel the underlying cause of this disconnect is the lack of a clear vision for the future of NASA. Once that vision is created, once a mission is designed, I believe that the needs to fulfill that mission will become much more obvious. As we decide the needs, I am confident that American policy-makers, American scientists and engineers, and the American people will step up the plate and launch us into the next millennium. The first step though, must be the vision.

Today we will hear about the Integrated Space and Transportation Plan and the Orbital Space Plane Program. Obviously, we have two primary needs—carrying people into space and carrying cargo. The Space Shuttle has been able to do both, but regardless of the outcome of the CAIB investigation, it seems that using the shuttle until 2020—when its technology will turn about 50 years old—might not be the best we can do. The ISS is now achieving functionality after billions of dollars of investments, and we are talking about staffing it with only two or three crew members. Having such a magnificent facility going unused during sleeping hours for the two-person crew seems absurd. Also we may be putting the astronauts at risk because if one of them becomes sick, it may be impossible for the other to provide help while performing all of the other necessary duties to keep the ISS running.

It seems that we are close to glory in space, but are just not demonstrating the necessary commitment, and boldness. I want to hear what goals the ISS can achieve, and how many people it would take to achieve those goals. Then we can make an informed decision on what kind of vehicle we need to get them there, and how best to bring them back in the case of an emergency.

If the Orbital Space Plane will not be up and running fully until 2012, and the ISS is scheduled to end operations in 2016—is it worth the investment? I would guess that it is, if it is going to be used for other purposes after the ISS is shut down, or if the ISS lifetime is going to be extended. What will those other purposes be, and what is the future of the ISS? I assume that since we are running it at one-third capacity—there will be plenty of work left to do come 2016. Again, we need a statement of purpose and of vision, from the Administrator, or it will be nearly impossible to decide on the credibility of the OSP program.

I am looking for some thoughtful, creative strategies to get NASA back on track. NASA has a challenging puzzle before it in designing the crew and cargo transport systems of the future. But I am confident that rising to challenges is what NASA does best.

Thank you.

Chairman ROHRABACHER. And let me note before I introduce the witnesses that I will be chairing this hearing today. But as usually happens, here we are, we are complaining about the way other people organize their aspect of the Federal Government. I am a senior Member of the International Relations Committee, and we are marking up the most important bill of the International Relations Committee, of course, our authorization of the State Department as we speak today. So I will be having—I am sure I will be called out once or twice to make sure I get to a rollcall vote over in that Committee. And I apologize to those of you who are here as witnesses.

I—and I really am very grateful for you to be here, but I have got that responsibility, too, so that is why I am running back and forth. And when I run out, I believe Mr. Calvert will be—Mr. Calvert won't be taking over for me. It won't be Mr. Gordon. We are not going to give it to him yet. Okay. One of my other colleagues will be taking over during that time.

So we have a distinguished panel with us today to provide their unique perspective to this critical, critical issue in terms of Space Station and how—and our Crew Return Vehicles and how we are going to get up and back. And so we have asked them to summarize their statements and their testimony into five minutes, if possible, and we would appreciate that very much.

Our first witness, Fred Gregory, is the Deputy Administrator of NASA. He is well known to all of us, and we are very, very appreciative that he is here today. Mr. Gregory, you may proceed.

STATEMENT OF THE HONORABLE FREDERICK D. GREGORY, DEPUTY ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. GREGORY. Thank you very much, sir, Members of the Subcommittee. I always welcome an opportunity to appear and share the plans and progresses that we are making toward our implementation of the NASA Integrated Space Transportation Plan and the development of the Orbital Space Plane Program.

Mr. Chairman, before I start, though, I would like to thank the Science Committee, and, in particular, recognize Chairman Boehlert for his leadership and support in introducing H.R. 1085, the NASA Flexibility Act, which provides many of the human capital provisions that we feel are critical in our ability to reconstitute and reconfigure NASA's work force. We are hopeful that this bill will be enacted expeditiously this year.

Mr. Chairman, you requested that I would address a number of topics related to ISTP and the Orbital Space Plane system, and I have responded to those questions within the written testimony. During my oral testimony, I would like to highlight several important points relative to the ISTP and OSP.

NASA's updated ISTP plan was driven by NASA's new vision and mission and supported by a comprehensive series of studies and reviews that determined a more beneficial course of action for NASA affecting many of the agency's major programs. These budget changes reflect the interrelationship and tight coupling among our Space Station, our Space Shuttle, and the SLI programs to support breakthrough research in science and space. They were achieved within our budget, enabling NASA's overall program to be responsible, credible, and compelling.

The ISTP program provides an integrated and systematic approach to our space transportation needs. The plan sustains the Shuttle through at least the middle of the next decade, aggressively pursues crews transport and rescue systems, called the OSP system, and continues the development of the technologies that will enable future launch systems. This plan allows NASA in the near future to ensure that the Station can achieve U.S. Core Complete ready to accommodate the international partner modules and better addresses the scientific research priorities.

In addition, we have established the position of the NASA Space Architect, reporting to me to ensure our integrated approach remains consistent within NASA's vision and mission. Under the leadership of the Space Architect, NASA is aggressively studying long-term science and exploration goals to provide further guidance that will better inform these critical decisions.

Mr. Chairman, I would like now to turn my discussion to the measurable progress we have made on the OSP program since releasing the updated ISTP plan in November of 2002 as part of the fiscal year 2003 budget amendment. Within the OSP program, a program office has been established and management of the program has a direct reporting path to NASA headquarters. Clear, concise Level 1 requirements for the OSP program have been established, which identify the critical, top-level specifications that the OSP system must meet without dictating a design solution.

The trade space is open for innovative design solutions from industry to best meet NASA's needs. There is no preconceived notion on what the ultimate vehicle design will be, whether it would be a winged vehicle, a lifting body shape, or a capsule. Each of these shapes has competitive advantages and disadvantages that will be explored during the formulation studies. Our requirements do not specify whether the crew rescue and crew transport requirements are met with a single vehicle, by similar vehicles adapted from a common airframe, or by completely different designs.

The final design will be selected based on the ability to meet all of the Level 1 requirements. The Shuttle will likely remain a workhorse for the agency throughout the—at least the middle of the next decade, consistent with the framework of the ISTP program plan. The Shuttle is required to complete the Station assembly and to perform other critical NASA science missions, such as servicing and perhaps returning the Hubble Space telescope.

In addition, its heavy lift capability and ability to return cargo to Earth from the Station will continue to be used until a viable system is developed to perform these functions. We will use the results of mission model studies to better guide our operational strategy on the best use of to space transportation resources available for the Station to guide our investment strategy supporting the ISTP, including consideration of alternate cargo concepts, and to influence the Level 2 performance requirements.

Mr. Chairman, the loss of the Space Shuttle *Columbia* and her crew is a national tragedy. We are committed to a safe return to flight as quickly as possible, but only after the cause of the accident is fully understood based on findings by the *Columbia* Accident Investigation Board and corrective measures are implemented and independently assessed by a task team led by General Tom Stafford.

We are conducting an agency study, led by the NASA Space Architect, to be completed by this summer to review each leg of the ISTP road map and each key decision to determine if changes are warranted. We will incorporate our responses to the—Accident Investigation Board recommendations into this ISTP update. Importantly, we are conducting the ISTP update with an eye toward our future needs. We will pursue building blocks that provide the transformational technologies and capabilities that will open new pathways of exploration and discovery and lay the foundation for future human and robotic missions to Earth's neighborhood and beyond.

A series of studies have been conducted to evaluate whether it is feasible to accelerate the OSP program development schedule. The studies identified a possible 6-month to 1-year schedule acceleration for the crew rescue capability and a potential savings of one to two years for the crew transport capability. Cost implementations of accelerated efforts are still being assessed and no final conclusions as to the feasibility have been made.

Mr. Chairman, in summary, significant progress has been made toward implementing the OSP program since its introduction of— in November of last year. NASA is committed to safe return to flight following the *Columbia* tragedy, and I want to thank you for my opportunity to address the Subcommittee.

[The prepared statement of Mr. Gregory follows:]

PREPARED STATEMENT OF FREDERICK D. GREGORY

Mr. Chairman and Members of the Subcommittee:

Thank you for this opportunity to appear before you and share the plans and progress we are making toward implementation of NASA's Integrated Space Transportation Plan (ISTP) and development of the Orbital Space Plane (OSP) system.

Mr. Chairman, you requested that I address a number of topics related to the ISTP and particularly the OSP Program. I will respond to these questions by first discussing the studies performed for the ISTP that led to the FY 2003 Budget Amendment submitted in November 2002. Then I will discuss the progress made toward implementation of the ISTP, and particularly the OSP Program, and, finally, I will address our approach to the reevaluation of the ISTP as a result of the *Columbia* tragedy.

Introduction of the New Integrated Space Transportation Plan

NASA's updated ISTP is driven by NASA's vision and mission and supported by a comprehensive series of studies and reviews that determined a more beneficial course of action for NASA, affecting many of the Agency's major programs. These budget changes reflect the interrelationship and tight coupling among the Station, Shuttle, and SLI programs to support breakthrough research in Space. They were achieved within our budget—enabling NASA's overall program to be responsible, credible, and compelling. The updated ISTP resulted in the restructuring of the SLI, and other adjustments, to accomplish the following:

- Extend safe Shuttle operations through at least the middle of the next decade;
- Ensure NASA's ability to achieve Space Station Core Complete, meet international commitments, and provide a robust orbital research program by increasing Station reserves, consistent with independent review recommendations, and by increasing the Shuttle flight rate to adequately support scientific research priorities aboard the Core configuration;
- Fund long-lead items for enhanced ISS research that preserve the option of expanding the ISS crew above three;
- Begin development of a new Orbital Space Plane system that yields crew rescue and crew transport capabilities; and, to make this possible, the ISTP also
- Defers development of a next-generation of launch vehicles until long-term goals are adopted that can justify the expense.

Resulting budget changes reflect the interrelationship and tight coupling among the Station, Shuttle, and SLI Programs to enable humans to conduct breakthrough research in space. Achieving success in the assembly and operation of the ISS drives launch demands for the Space Shuttle, our international partners' vehicles and the OSP system. Similarly, the expected lifetime of the ISS, coupled with the potential for enhanced research and expanded crew post Core Complete, as well as our plans for future exploration goals, will drive potential future launch requirements.

The ISTP provides an integrated and systematic approach to our space transportation needs. The plan sustains the Shuttle through at least the middle of the next decade; aggressively pursues crew transport and rescue systems, called the Orbital Space Plane system; and continues the development of the technologies that will enable future launch systems. This plan allows NASA, in the near-term, to ensure that the ISS can achieve U.S. Core Complete, be ready to accommodate the International Partner modules, and better address scientific research priorities. In addition, we have established the position of the NASA Space Architect, reporting to me, to ensure our integrated approach remains consistent with NASA's vision and mission. Under the leadership of the Space Architect, NASA is aggressively studying longer-term science and exploration goals to provide further guidance that will better inform these critical decisions.

Background: Original Aim of the Space Launch Initiative

To aid in addressing our thought process in the formulation of our new ISTP, I would now like to reflect on the original aim of the Space Launch Initiative. In the late 1990's, NASA sponsored the *Space Transportation Architecture Studies* to examine candidate architectures for a new reusable launch vehicle and to assess the launch market outlook. Both NASA and its contractors concluded that the market was too small for industry alone to finance a new launch vehicle and thus, development would place a significant cost burden on the U.S. government. In addition, it was concluded that a two-stage-to-orbit RLV could have many desirable performance characteristics and would be within reach of existing technologies. As a result of these studies, NASA proposed the SLI, initiated in the President's FY 2001 budget. The SLI Program's stretch goals included reducing the cost of space access to $1,000 per pound to Low Earth Orbit and reducing the probability of loss of crew to 1 in 10,000 for a second generation RLV. The SLI Program planned to spend $5 billion over five years to develop critical technologies and architecture concepts that would reduce the risk of this approach, prove that these goals were attainable, and support a decision by 2005 whether or not to build an operational RLV.

This SLI Program was part of a larger investment strategy that tied together NASA's various space transportation efforts. The strategy, the original ISTP, included milestones, decision gates and off-ramps for SLI, Space Shuttle, and third-generation air-breathing hypersonic technologies. This is the ISTP that served as the basis for the original FY 2003 Budget request.

The projected government investment in SLI was based on the assumption that the development cost of a new RLV would be amortized across both the commercial and NASA launch markets. The NASA market is currently dominated by the needs of the Space Station program that requires nearly full use of the Space Shuttle. Consequently, the RLV design was driven by unique Space Station requirements that included cargo and crew transported into orbit, rendezvous and docking with the Station, and return of cargo and crew to a landing site. To ensure the safety of the crew, the new design of the RLV would be certified as human-rated.

Unfortunately, the key assumptions proved too optimistic. The commercial market continued to decline. It was premature to base new RLV requirements on other potential markets, such as DOD or future NASA exploration missions. Revised estimates of the development cost of a new RLV were well above the original estimate. Given the uncertainty of the market and the higher cost of RLV development, NASA concluded that the economic case for a new RLV was in doubt for the foreseeable future.

Options Considered for the New Integrated Space Transportation Plan

As a result, NASA decided to examine alternatives prior to making the large commitment required for full-scale development of the vehicles under study. NASA undertook an evaluation during the summer of 2002 to examine possible options for the ISTP and SLI. The options studied included:

Option 1—Maintain the baseline ISTP program that assumed a decision in 2006, to concurrently build a new RLV two-stage booster and a crew transport vehicle to deliver crew to and from orbit. The new RLV could replace the Space Shuttle as early as 2012.

Option 2—Develop an Orbital Space Plane system and delay the RLV Booster. This option built an OSP system by 2010–2012 to be flown on an Expendable Launch Vehicle (ELV) that would be human-rated. In this option, the RLV booster development was delayed.

Option 3—Develop a prototype RLV booster by around 2011. This option built a common RLV prototype booster with DOD. In this option, an operational booster and Orbital Space Plane would occur later.

Option 4—Breakthrough Technology. This option focused on long-term, high-payoff technologies, like hypersonic propulsion, and indefinitely delayed a new RLV.

The ISTP options were evaluated based on the following factors and criteria:

Safety—the potential for improved crew survivability through development of an ISS crew return vehicle and a crew escape system on a crew transport vehicle.

Assured Access—the provision of alternate independent means of meeting launch requirements despite potential launch mishaps, Space Shuttle groundings, or shortfalls in partner contributions to Station needs.

Economics—the affordability within the budget outlook and the potential for future cost savings.

Flexibility—the ability to evolve capabilities and adapt to changes in future launch requirements that remain uncertain.

These option studies were complemented by a number of other studies, including:

SLI Second Generation Reusable Launch Vehicle and Crew Transport Vehicle Development Studies, conducted by the SLI Program Office in 2002, evaluated hundreds of alternative space transportation system designs and performed in-depth evaluation of the 15 best candidates. A conclusion from these studies was that separating crew transport and cargo delivery functions would provide the optimum approach to improving crew safety and decreasing costs.

A *Crew Transfer Vehicle/Crew Rescue Vehicle Study,* conducted by the SLI Program in 2002, concluded that a multi-purpose Orbital Space Plane that can perform both the crew transfer and crew return functions for Station is viable and could provide the most long-term benefit for NASA's investment.

An *ISTP Study by the NASA Independent Program Assessment Office* in 2002 concluded that it was premature to commit to an RLV development, except that an Orbital Space Plane launched on an Expendable Launch Vehicle promised a number of benefits, including crew return from Station, assured crew access to space, potential enhanced safety for crew transfer and crew return, and a potential long-term Space Shuttle replacement strategy.

The *SLI Level One Requirements effort* conducted by NASA Headquarters and the SLI Program Office in 2002 indicated it was premature to commit to Level One requirements for a next-generation RLV.

The *120-Day Joint NASA/DOD Study* conducted by the SLI Program Office and various Air Force organizations in 2001–2002 concluded there was common interest and benefit in development of the first stage of a two-stage RLV using a kerosene-fueled engine.

The *National Aerospace Initiative and the National Hypersonics Plan* developed by NASA and DOD in 2001–2003 chartered a joint NASA/DOD roadmap for technology development of an advanced space transportation system.

The *Space Shuttle 2020 Study* completed in 2002 concluded that the Shuttle lifetime could be extended to 2020. However, additional investments would be needed to preserve and improve Shuttle safety and maintenance beyond 2012.

Based on the criteria and information from the complementary studies, NASA chose Option 2—Develop an Orbital Space Plane system and delay the RLV Booster. The OSP Program concept promises a number of benefits that rank well against the criteria for safety, economics, assured access and flexibility.

It is aimed at providing assured crew access to the ISS, improving crew safety, meeting the U.S. ISS crew return requirements from the ISS, and providing a bridge to the future by demonstrating technologies on a new crewed vehicle and supporting enhanced science on the Space Station. In summary, key changes to the ISTP roadmap which resulted from this decision were to extend the Shuttle lifetime from 2012 to at least the middle of the next decade and to delay the decision to develop an RLV booster from 2006 to no earlier than 2009.

The new ISTP consists of three major programs: the Shuttle, OSP, and Next Generation Launch Technology (NGLT) Programs. The OSP and NGLT Programs are both managed within the restructured Space Launch Initiative. No strategy is without risk. Some of the key risk items within the ISTP that we must address include:

- The ability to sustain the Space Shuttle fleet to safely meet its service life requirements;

- The design and integration of the Orbital Space Plane flight vehicle(s) onto an Expendable Launch Vehicle including the associated human rating of the system and ground launch processing needs;
- The ability to meet our objectives in the event of another Shuttle loss or extended down time; and
- The ability to meet each of these objectives within a responsible and credible budget.

Our approach to mitigating these risks is to consistently address the issues using an integrated approach within the framework of the ISTP. By pursuing multiple paths with interim decision points, we are less susceptible to technical issues and more flexible in dealing with changing requirements. We are striving to implement robustness in our design solutions and ensure that our investment strategy provides the greatest overall benefit to the Agency. The OSP program is a prime example, providing multiple benefits including assured crew access to space, meeting the U.S. commitments for crew return from the ISS, improving crew safety, and providing a bridge to the future. We believe the OSP system will, in combination with other launch systems, provide the vital human transport capability necessary to retire the Shuttle. Finally, the NASA Space Architect will ensure an integrated approach is taken to resolve any issues and remain consistent with NASA's vision and mission.

An important feature of the new ISTP is the linking of key decisions across the three space launch programs and NASA's long-term strategy. The next two years are critical for a series of decisions that will occur in the 2004 to 2005 timeframe. These decisions include: whether to compete for long-term contracts for Shuttle operations; whether to proceed into the full-scale development phase of the OSP; and whether to aggressively pursue a new launch vehicle or instead pursue a long-term technology program in pursuit of breakthrough technologies. These decisions will also be linked to the expected lifetime of the ISS, as well as any new space transportation requirements for exploration beyond low earth orbit. Currently, the ISS Program assumes Station mission life through at least the middle of next decade, and likely extending into the following decade. NASA plans to aggressively study longer-term exploration goals to provide further guidance that will better inform these critical decisions.

Progress Made on the Orbital Space Plane Program

Mr. Chairman, I would now like to turn my discussion to the measurable progress we have made on the OSP Program since releasing the updated ISTP in November 2002 as part of the FY 2003 Budget Amendment.

Within the OSP Program, a program office has been established and the management team has been put in place, with a direct reporting path to NASA Headquarters. NASA expertise is being provided from across the Agency to ensure program success, embodying the One NASA philosophy of an integrated NASA working together. Clear, concise Level 1 Requirements for the OSP Program have been established and approved by the Agency. These requirements identify the critical top-level specifications that the OSP system must meet without dictating a design solution within the requirement. Key requirements include providing rescue capability for no fewer than four Space Station crew members as soon as practical, but no later than 2010; and providing transportation capability for no fewer than four crew members to and from the Space Station as soon as practical, but no later than 2012. The OSP system must improve crew safety relative to either the Space Shuttle or the Soyuz; offer increased on-orbit maneuverability and increase the launch probability relative to the Space Shuttle; and require less time to prepare and execute a mission as compared to the Space Shuttle. The OSP system for crew rescue must also provide for rapid separation from the Space Station under emergency conditions and allow the safe return of deconditioned, ill or injured crew members with ongoing treatment until arrival at definitive medical care within 24 hours; a capability not currently available to the astronauts on the Space Station. The OSP system must meet these requirements and all applicable Space Station requirements while minimizing life cycle costs.

The trade space is open for innovative design solutions from industry to best meet NASA's needs. There is no preconceived notion on what the ultimate vehicle design will be—whether it is a winged vehicle similar to the Space Shuttle, a lifting body shape like that of the X–38, or a capsule similar to the Apollo command module. Each of these shapes has competitive advantages and disadvantages that will be explored during the formulation studies. Our requirements do not specify whether the crew rescue and crew transport requirements are met with a single vehicle, by similar vehicles adapted from a common airframe, or by completely different designs.

The final design will be selected based on the ability to meet all of the Level 1 requirements.

A Systems Requirements Review will be conducted this fall to establish an integrated set of NASA Level 2 Requirements to provide further definition in support of the conceptual design activities. Three competing industry teams are under contract to perform trade studies, develop conceptual designs, and develop detailed Level 3 Requirements in support of a Systems Design Review to be held during the summer of 2004. This information will be used along with independent assessments performed by NASA and other external review committees to support a decision on whether to proceed with the full-scale development of the OSP flight system in September 2004. A full-and-open competitive procurement for the design, development and production of the OSP system will be held next year leading to contract awards in late 2004 if a positive decision is made to proceed with full-scale development.

The Space Shuttle will likely remain a workhorse for the Agency through at least 2015, consistent with the framework of the ISTP. The Shuttle is required to complete the ISS assembly and to perform other critical NASA science missions such as the servicing of the Hubble Space Telescope. If the OSP proves sufficiently safe and reliable, it could ultimately replace the Shuttle as the primary crew transport and, thus, free up Shuttle to focus on cargo functions, or, possibly, a heavy lifter for ambitious science-driven research missions. We will use the results of mission model studies to better guide our operational strategy on the best use of the space transportation resources available for the ISS; to guide our investment strategy supporting the ISTP including consideration of alternative cargo concepts; and to influence the Level 2 performance requirements to be placed on the OSP Program. Our intention is to focus the Shuttle on the most critical functions that it alone can provide while meeting the ISS logistics needs, providing assured access to Station to ensure science objectives are met, and improving crew safety. The OSP system will be an integral part of that strategy.

NASA is committed to providing responsible, credible cost and budget estimates prior to committing to new development programs. We will be following NASA policy guidelines of using the formulation phase of the OSP Program to establish cost and schedule commitments for the implementation phase. At that point, the requirements and conceptual design will be sufficiently understood to ensure a responsible and credible development cost commitment is made. As part of the OSP system design process, each competing architecture contractor is providing life cycle cost estimates as a major deliverable. Government cost experts are developing cost estimates in parallel, utilizing legacy cost data from prior programs along with improved and validated cost analysis and estimating tools. A Cost Credibility External Review Team, reporting to the OSP Program Manager, is being established to provide expert assistance in ensuring credible cost estimation. In addition, an independent cost validation will be performed utilizing a Cost Analysis Requirements Document, as used by the Department of Defense and on the ISS Program. These various cost estimates will be studied and understood prior to the Full Scale Development decision. In addition, we are ensuring fiscal accountability on all ongoing OSP Program activities by using a proven Earned Value Management system to track actual cost and schedule performance as compared to plans

Mr. Chairman, the estimates included in the President's FY 2004 budget request for the implementation phase of the OSP Program following the full-scale development decision are placeholder estimates only, until these life cycle analyses and independent cost validation exercises are performed. We are actively examining the near-term budget requirements for the OSP Program in support of the ongoing budget submittal cycle to ensure adequate funding is maintained.

Flight Demonstrations

In addition to the OSP Program requirements definition and conceptual design activities, several flight demonstrator projects are in place to test critical technologies in relevant flight environments and reduce the risk of developing a full-scale space vehicle. Validating ground-based testing and analysis is a necessary part of fielding a new space transportation system. Each of the OSP Program flight demonstration projects will produce data that can be directly applied to the entire range of potential system designs and was selected based on previous SLI studies identifying the most critical flight demonstration needs. Each was selected under a full-and-open competition to produce data that will reduce the technical risk of a particular aspect of the OSP system regardless of the design finally chosen for full-scale development.

The Demonstration of Autonomous Rendezvous Technology (DART) flight demonstration will demonstrate automated rendezvous technology and proximity operations between a chase vehicle and an on-orbit satellite, validating an advanced video guidance system that is needed to perform similar operations for the OSP system. In addition, NASA is working with the Department of Defense on related projects such as the *Orbital Express* to further demonstrate the technology, which has utility for both agencies. The DART vehicle is nearing the end of the manufacturing and integration phase and is being prepared for system integration testing.

The Pad Abort Demonstrator (PAD) is a full-scale platform for testing and assessment of crew escape technologies. Adding to the experience base from the Mercury, Gemini and Apollo Programs, the PAD Project will demonstrate crew escape and survivability systems utilizing current technologies by performing an end-to-end launch pad abort demonstration. Fully instrumented mannequins will generate data on crew environments during testing of propulsion and parachute systems, orientation and landing techniques, and external structural configurations.

The X–37 technology demonstrator is an integrated platform to validate approximately 30 high-priority technologies in the orbital and re-entry environments. The X–37 project consists of two distinct flight demonstration vehicles. An Approach and Landing Test Vehicle (ALTV) continued from an earlier full-and-open competitive procurement award, will validate pilot-less operations during approach and landing from an altitude of 40,000 feet and below after being dropped from a B–52 aircraft. The vehicle is currently in the manufacturing and integration phase.

The X–37 Orbital Vehicle (OV) will provide a versatile technology platform to validate important technologies and obtain environmental data during critical stages of the mission. It will be launched on an Expendable Launch Vehicle, operate autonomously on-orbit, and return to Earth.

The X–37 modularity allows for multiple advanced development demonstrations. Flight experiments can still be defined and incorporated into the Orbital Vehicle into the fall of this year without adversely impacting the overall project schedule. Key X–37 technologies to be demonstrated include: pilot-less guidance, navigation and control (including high crosswind landing and all-weather windward adaptive guidance); aero-thermal and flight profile data collection; multiple high temperature, wing leading edge, and durable acreage thermal protection system technologies; lightweight landing gear and phase change brake technologies; avionics and power technologies including high-energy/high-density batteries and electrical actuators for aero-surfaces; advanced high-temperature structures; and ground operations including rapid thermal protection system waterproofing. As a particular example where the X–37 will be used to demonstrate advanced technologies, the Space Shuttle uses a Thermal Protection System (TPS) primarily composed of carbon-carbon for the nose and leading edges, low-temperature thermal blankets in the low-temperature areas, and silicate blocks. This complex system is difficult to process and maintain. The X–37 will demonstrate the effectiveness of multiple advanced TPS technologies, including high-temperature ceramic leading-edge material, durable high-temperature blankets, and metallic TPS.

Two competing interests arise when integrating the flight demonstration projects into the Orbital Space Plane Program. The first desire is to perform the flight and technology demonstrations early in the design cycle (and ideally prior to the full-scale development decision) in order to assist in that decision. The counter desire is to defer flight demonstrations until the OSP system design is better defined in order to maximize the utility of the flight demonstration. Because of the long lead time required for flight demonstrator projects coupled with the time-critical urgency of the OSP Program, it is not practical to meet both desires. We believe that the present program achieves a balance between these competing interests. The DART automated rendezvous and X–37 Approach and Landing Test Vehicle flight demonstrations are scheduled to be completed prior to the Full-Scale Development decision. The PAD launch abort design will be completed and the X–37 Orbital Vehicle design will be nearly complete prior to the Full-Scale Development decision. The PAD and X–37 Orbital Vehicle flight demonstrations will be completed during the OSP program design period, allowing their results to be directly incorporated into the vehicle design.

It should be noted that all of the flight demonstrator contracts have built-in option periods to minimize the government's risk, in the event that the contractor fails to perform or the OSP Program concept definition studies determine that an alternative flight demonstration approach is required. This approach allows the government to end the contract without incurring termination penalties at the end of any option period should the need for redirection arise. For example, the X–37 base contract expires in September 2003 followed by an option period and a decision on a second option in August 2004. An independent cost estimate of the X–37 will be performed in support of the decision to implement the first option period of the contract. The second option decision point is consistent with the schedule for the OSP Program full-scale development decision. Using this approach, we believe we have adequately ensured that the demonstrations take place early enough to influence the OSP system design without exposing the government to excessive risk.

We believe these flight demonstrations represent a high value investment when considering the potential total development cost of the OSP system, and they will provide valuable quantitative data in support of the full-scale development decision, and that they will greatly mitigate risks during the development period. All of these flight demonstrations are crosscutting in their nature, and will provide technology data applicable to other potential future space transportation systems in addition to supporting the Orbital Space Plane system.

ISTP Reevaluation as a Result of the *Columbia* Tragedy

The loss of Space Shuttle *Columbia* and her crew is indeed a National tragedy. We are committed to a safe return to flight, as soon as the cause of the accident is fully understood, based on findings by the *Columbia* Accident Investigation Board (CAIB), and corrective measures are implemented and independently assessed by a task team led by Tom Stafford. We will finish the ISS assembly and optimize our ISS utilization, support our national space transportation goals, and build a foundation for possible future science and exploration goals.

We are conducting an Agency study, led by the NASA Space Architect, to be completed by this summer, to review each leg of the ISTP roadmap, and each key decision point, in order to determine if a change is warranted. We will incorporate our responses to the *Columbia* Accident Investigation Board recommendations into this ISTP update. Importantly, we are conducting this ISTP update with an eye toward our future needs. We will pursue building blocks that provide the transformational technologies and capabilities that will open new pathways of exploration and discovery, and lay the foundation for future human and robotic missions to Earth's neighborhood and beyond.

We are evaluating options to prioritize the Shuttle Service Life Extension Program (SLEP) to ensure a safe return to flight. A two-day summit was held in March to explore, discuss, and determine the best strategy to safely and effectively fly the Space Shuttle fleet to support key missions until at least the middle of the next decade. Recommendations from seven SLEP panels (Safety, Sustainability, Infrastructure, Aerospace Industry, Performance, Operations and Resources) provided recommendations to NASA's Space Flight Leadership Council. From this, 60 candidate projects were targeted for further consideration. A "Tiger Team" was established to prepare an internal submittal to support Agency decisions this summer as part of this ISTP review.

We are also re-evaluating whether we should more aggressively pursue a risk reduction program leading to a new launch vehicle to replace the Space Shuttle and support our future space exploration needs. We are working with the Department of Defense to ensure that any space transportation vehicle development or risk reduction activity is coordinated and that the investment will service both our agencies' needs to the maximum extent practical. In addition, we are re-examining whether we should place higher priority on providing assured U.S. cargo access to and from the Station and whether a development activity should be implemented in parallel to the assured crew access to be provided by the OSP system. Finally, we are examining the possibility of accelerating the OSP Program to provide an earlier alternative for crew access to space.

A series of studies have been conducted to evaluate whether it is feasible to accelerate the OSP development schedule. In order to determine the most rapid development schedule possible, the OSP established an independent review team of aerospace experts (Aaron Cohen, Vance Brand, Dale Myers, John Young, and Ken Szalai) to evaluate whether the proven Apollo Capsule could provide a relatively quick solution to crew rescue and crew transport requirements. The review team brought vast space transportation expertise and intimate knowledge of the Apollo Program to this study. The Apollo capsule is a potentially attractive solution since it was a robust design, its performance was well understood, and the full-envelope abort-and-recovery system was simple and safe. This study team concluded that, for a crew rescue vehicle, an Apollo derived vehicle that has the potential for meeting most of the Level 1 requirements could be available four to six years after contract award given adequate resources; hence, one to three years sooner than the OSP plans.

Additional findings of the Apollo Capsule study team were that while the Apollo system is well understood, virtually every system would have to be redesigned. In particular, the structure would need to be redesigned for compatibility with the internal pressure of the International Space Station. In addition, Apollo hardware could not be used due to obsolescence, changes in manufacturing techniques, and lack of traceability; the drawings could not be directly used due to incompatibility with modern systems; and life cycle costs would be strongly dependent on ground support systems and recovery site infrastructure.

In addition to this best-case schedule improvement, the OSP Program organized two other groups to provide an assessment of the schedule acceleration potential. The first group was a NASA-wide Focus Group consisting of representatives from several NASA Centers containing experienced Program and Project managers as well as "out-of-the-box" thinkers. The second group established was a multi-disciplined team from within the program. Both groups were to address alternative approaches to the OSP system design and development that could, given no funding or personnel constraints, result in schedule improvements by evaluating the current plans for each phase of the program. In addition to these internal teams, the OSP Program architecture contractors were solicited for their input on the acceleration possibilities. The studies identified a possible 6-month to 1-year schedule acceleration for the crew rescue capability and a potential savings of one to two years for the crew transport capability.

However, to accomplish an accelerated schedule, the following would be required:

- Conduct an early downselect of the shape and design concept. Select a single design to serve both the crew rescue and crew transport functions;
- Limit the requirements and keep them simple, focusing on the primary role of transporting crew;
- Develop the minimum flight vehicle test plan early in the program, including qualification test flights, and adhere to that plan; and,
- Provide additional reserves to allow recovery from issues and problems as they arise.

Cost implications of an accelerated effort are still being assessed, and no final conclusions as to the feasibility have been made. While the direct use of the Apollo heritage design does not appear to provide significant benefits, an advanced capsule remains a candidate that could be considered for the OSP system design. The results of these studies are being incorporated into the ISTP update study to determine an integrated NASA position once the data from all studies is available.

Summary

In summary, significant progress has been made toward implementing the OSP Program since its introduction in November of last year. The OSP Program Level 1 Requirements have been established, and the program schedule and acquisition strategy has been developed. The NASA/industry teams are in place to perform the conceptual design studies and flight demonstrations that will support a full-scale development decision by the end of FY 2004 and future detailed design decisions. The OSP Program provides a number of near-term and long-range benefits for the Agency. The new system offers operational flexibility for U.S. missions by providing assured crew access to the ISS and meeting the U.S. obligations for crew rescue. Safety will be improved beyond that of the Space Shuttle and Soyuz. In addition, the OSP Program builds a bridge to the future by the experience gained from designing and developing the system and by enabling increased Space Station crew size and resultant science benefits.

The new ISTP represents a flexible roadmap to guide our space transportation investment strategies. NASA is committed to safe return to flight following the *Columbia* tragedy and to create new capabilities for continued exploration and development of space. As we look forward, we will continue to use an integrated approach to guide our investment strategy and to ensure a responsible, credible plan.

Thank you for this opportunity to address the Subcommittee.

Chairman ROHRABACHER. Thank you very much. Mr. Gregory, I just—this is an unpleasant part of my responsibilities, but your testimony was very provocative, but we needed to look at it. We didn't get it until yesterday. And I don't—my guess is that you have got a pretty good staff. It does not reflect well on you or your staff when this committee does not have the time to examine your testimony to make sure that this hearing is as meaningful as it should be. And I would advise you that you should make sure that that testimony is in on time in the future.

Mr. GREGORY. Understood, sir.

Chairman ROHRABACHER. Okay. Thank you. Next, we have Dr. Jerry Grey, who is Director of Science and Technology Policy at the

American Institute of Aeronautics and Astronautics. And he is, again, like most of our other panelists today, very well acquainted with this committee, and we are very appreciative that he has joined us today to loan us his expertise. You may proceed.

STATEMENT OF DR. JERRY GREY, DIRECTOR OF AEROSPACE AND SCIENCE POLICY, AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS

Dr. GREY. Thank you, Mr. Chairman. As with Mr. Gregory, my written statement has answered the 18 questions you posed. Since there is no way I can address them in five minutes, I am just going to hit the high points.

First, the ISTP. It has three elements. The Next-Generation Launch Technology Effort should be strongly supported. For years, the AIAA has decried the lack of an ongoing program to advance and upgrade space transportation systems, that is to have each successive generation of launchers in the pipeline to succeed the current generation. It is the lack of such a program in the past that has led to the current crisis in space transportation.

The Shuttle Service Life Extension Program should also be supported, because for the foreseeable future, as everyone has noted already, the Shuttle will be essential to Space Station operations. We now have only three Orbiters, and the likelihood of another Shuttle failure in the next 10 to 15 years can not be ignored.

Finally, the Orbital Space Plane. Now if we assume successful, on-time development of the OSP, the OSP EELV architecture suggested by NASA does, indeed, meet their critical needs. But that is a big if. The OSP isn't even a paper vehicle yet. And Mr. Chairman, as you have pointed out, NASA's record for on-budget, on-schedule development of new space launchers leaves some doubt as to whether it will really be available on the proposed dates. One troubling factor, again, is the current OSP development cost estimate, which ranges from 9 billion to 13 billion, although admittedly premature. NASA might be better off to pursue an evolutionary OSP development, which I will discuss later.

In summary, the revised ISTP is neither overly optimistic nor overly conservative. The new OSP EELV architecture does make sense, but it is too early to assess the risk involved in OSP development or the soundness of its cost estimates.

On continuing Shuttle operations, there is one overriding reason for NASA to maintain the Shuttle: space transportation will remain a high-risk activity for the foreseeable future, so reliance on a single system could once again precipitate a crisis much like the present one should the OSP system fail or be grounded. Neither the Russian nor the European access capabilities can be counted upon.

In my written statement, I have cited several other strong reasons for maintaining the Shuttle. The only real negative is a big one, of course, the additional cost of maintaining the Shuttle fleet. With the OSP, the Shuttle could be kept on a standby basis, flying only when needed, but that raises safety concerns and doesn't reduce the Shuttle infrastructure, which absorbs the bulk of Shuttle costs. The safety issue could be addressed by having the SLEP reduce the Shuttle crew and provide a flight deck escape capsule, which doubles the chances for crew survival. However, the best way to address both cost and safety issues of the Shuttle would be to equip the Orbiters for fully autonomous operation.

If we look at design alternatives, as Mr. Gregory has stated, NASA has suggested that the design trade space for the OSP is essentially open, but it would make sense to develop the required functions, crew return and transport, serially rather than in parallel. The urgent need is for station crew rescue. Why not seek the lowest cost design approach to meet that requirement and then use the experience gained to develop the transport capability? There are at least two viable, low-cost design options for crew rescue: the original X–38 CRV concept, which Mr. Gordon mentioned, and an Apollo-derived capsule, which Mr. Myers, I think, is going to address at length in a few minutes. I have mentioned several other possibilities in my written statement.

An evolutionary OSP development program would provide crew return at the earliest possible time with low risk. With the Shuttle fleet operational, OSP transport capability is not urgently needed and hence could be stretched out to reduce both risk and budget impact. Some urgent cargo needs could be met by resurrecting the Alternate Access to Station Program, as you have recommended, Mr. Chairman.

Now there are some challenges in using ELVs with the OSP. The primary challenge is safety, but that is true for any launch system, not just ELVs. The current failure rate, that is loss of mission, of the partly reusable Shuttle is now 2 in 114, or about 1.75 percent. The current failure rate of the Delta 2 ELV is 3 in 125, or about 2.4 percent, and of the Atlas 2 to 5 family is 0 in 64. Any residual safety risks can and should be reduced by an effective OSP crew escape system.

Hence safety is a challenge, but the risk of flying people on an ELV is certainly not unacceptable. The Soyuz launcher on which we now rely for all Space Station crew operations is expendable, as were the Atlas, Titan, and Saturn rockets used for Mercury, Gemini, and Apollo without a single launch failure. I have talked about other challenges in using EELVs in my written statement. None of them pose insurmountable problems.

There are trade studies that need to be done. Besides examining serial versus parallel OSP development, a temporary cost-saving option that should be explored is to extend the on-orbit lifetime of the Shuttle fleet so as to allow an Orbiter to remain at the station for extended periods, thereby serving both the functions for the OSP. This approach has obvious disadvantages, which I have cited in my written statement, but it would remove the time pressure on OSP development and would also, and this is important, provide a crew of seven to ten people for both Station maintenance and science research. I have discussed other trade studies in my statement.

You asked about technology demonstrations. A flight demonstration is, by far, the most effective mission-assurance tool; hence the planned X–37 program as well as the proposed DART and Pad Abort demonstrations are of high value to OSP development and should certainly be retained.

In closing, I would like to suggest a possible scenario for optimum servicing of the station. First, the Shuttle SLEP effort should be initiated immediately and should include the following elements: one, convert the four-person flight deck to an escape capsule for all flight modes; second, provide the Orbiters with the option for fully autonomous operation; and third, equip two Orbiters for orbital stays of at least four months. As soon as one Orbiter is equipped for long-term stays on orbit, it should be flown to the Station and based there for four more months. Until the OSP crew return version has been demonstrated, the two Orbiters suitably equipped should alternate with each other.

Meanwhile, the NGLT program should be pursued and evolutionary development of the OSP should be conducted. OSP flights to the station should begin as soon as the crew return function has been demonstrated, relieving the on-orbit Shuttles. When the OSP transport function has been demonstrated, the Shuttle should be placed on a standby basis for autonomous operation to fly when needed for lifting large payloads to the station, for crew and cargo transport up and down during any OSP stand down, and also for ambitious NASA science and exploration missions in the solar system. Smaller Station cargo needs could be met by one of the Alternate Access to Station designs should NASA choose to resurrect them.

Thank you for this opportunity to address you, Mr. Chairman, and that completes my statement.

[The prepared statement of Dr. Grey follows:]

PREPARED STATEMENT OF JERRY GREY

Introduction

My name is Jerry Grey. I am Director of Science and Technology Policy for the American Institute of Aeronautics (AIAA) and Visiting Professor of Mechanical and Aerospace Engineering at Princeton University. Although the views I express here on the orbital space plane program and related subjects are consistent with those appearing in the AIAA's publications, they are my own and do not necessarily reflect the formal position of the AIAA. Thank you for this opportunity to offer my comments on this important subject.

As you requested, I focus my testimony on the questions you posed.

(1) What key factors should be considered when evaluating human space transportation architectures?

There are two principal factors: safety and cost. Included in "safety" are avoidance of failures, tolerance of failures (i.e., no injury to the crew) should a failure occur, and adequate life-support systems and provisions. Note that "tolerance of failures" implies consideration of crew escape systems. Included in "cost" are development and operational costs, broken down into annual budget requirements and life cycle cost.

(2) Is the proposed ISTP an overly optimistic or overly conservative approach to meeting NASA's needs? What areas of the proposed approach pose the greatest risk? What recommendations do you have to reduce these risks?

NASA's needs

It is first necessary to define NASA's needs. By far the most critical *current* need is to meet the International Space Station's transportation requirements. Prior to the loss of *Columbia,* the Shuttle fleet provided the large-payload capability needed to transport major elements of the International Space Station (ISS) and carried ISS crew members to and from the station, along with sizable amounts of both technological cargo (e.g., experiment apparatus) and expendables (e.g., water). Once the remaining Shuttle fleet returns to flight status, those functions can resume. When that will be, however, is still uncertain.

Additional provisions and emergency crew return capability for up to three ISS crew members have been provided by Russian Soyuz and Progress vehicles. The Russians are committed to provide Soyuz crew-return capability until 2006, and although funding for the number of Progress vehicles needed to continue ISS supply flights without Shuttle support has yet to be identified, there are “workarounds” that are likely to allow the station to function at least minimally until the three Shuttles return to flight status. These include measures already implemented; i.e., using Soyuz lifeboat-replacement flights to transport ISS crew members up and down and reducing the ISS crew to two; finding ways to finance an increase in Russian Progress operations; and using the European Automated Transfer Vehicle (ATV), whose initial launch aboard an Ariane-5 is planned for late next year (assuming the Ariane-5 will have successfully returned to routine service by then). The main near-term concern is that if no source of funding for additional Progress flights can be found, it may become necessary to mothball the ISS late in 2003 or early in 2004 until the Shuttle fleet returns to flight status.

NASA’s other needs for space transportation, other than one more servicing mission to the Hubble telescope, do not require the Shuttle’s unique capabilities and can be met by the existing Expendable Launch Vehicle (ELV) fleet. Hence the principal requirements for the ISTP, as far as NASA’s specific needs are concerned, are (1) to provide an alternative to the Shuttle fleet for servicing the ISS, especially after the next Shuttle failure occurs (at least one such failure is highly likely if the Shuttle is required to operated until 2015 or perhaps even 2020), (2) to provide ISS crew rescue capability after the Russian Soyuz commitment expires in 2006, and (3) perhaps most important, to provide rescue capability for an ISS crew larger than the present 3-person complement. This latter requirement is critical in order for the ISS to fulfill its purpose as a viable research facility. Cancellation by NASA of the original Crew Return Vehicle (CRV) program in February 2001 created this new requirement, which is of major concern to our foreign ISS partners as well as to the U.S. science community.

There is another important function for the ISTP, however: to provide the technology advancement and demonstration necessary to support major improvements in future U.S. access to space. Although not a specific NASA “need,” this is clearly part of NASA’s overall mission as defined by the 1958 NASA act. Without such improvements *all* elements of the U.S. space program—commercial, civil, and military—cannot proceed very far beyond what we are able to do today.

The ISTP

The amended ISTP proposal has essentially three primary elements: a Shuttle Service Life Extension Program (SLEP), the Orbital Space Plane (OSP), and development of Next-Generation Launch Technology (NGLT), the latter two of which constitute a revised Space Launch Initiative (SLI).

Next-Generation Launch Technology

The expansion of the former Generation 3 technology program into the NGLT, as well as the increased emphasis placed on this type of effort in the amended proposal, should be strongly supported. For many years the AIAA has decried the lack of an ongoing program to advance and upgrade space transportation systems; i.e., to have each successive generation of launch systems “in the pipeline” to succeed the current generation. This is relatively standard practice in both the automotive and the aviation industries. It is the lack of such a program in the past that has led to the current crisis in space transportation. The NGLT also incorporates technology advances being pioneered by the DOD, including those of the Director of Defense Research and Engineering’s (DDRE) National Aerospace Initiative (NAI) and the Air Force Space Command’s Operationally Responsive Spacelift (ORS) program, thereby strengthening not only the NGLT’s technical base but also the potential user base for future launch systems.

One area for concern, however, is the NGLT’s focus on hydrocarbon-fueled first-stage designs for the future Reusable Launch Vehicle (RLV). Although some offices of the Air Force (mainly the laboratory community) also favor hydrocarbon fuels, a definitive summer hypersonics study conducted by the Air Force Scientific Advisory Board in 2000 concluded that a hydrogen-fueled first stage would be optimum for both rocket-powered and airbreathing-propelled designs.

The planned NGLT also reduces the emphasis on rocket-powered launch systems in favor of airbreathing combined-cycle propulsion. Hence an excellent propulsion prospect, the robust high-thrust, high-pressure, high-performance expansion-cycle engine, a derivative of the ultra-reliable RL–10 (which has employed an expansion cycle with great success for four decades), will receive little or no attention in the NGLT.

Shuttle Service Life Extension Program

The Shuttle SLEP should also be supported, because for the foreseeable future the Shuttle will be essential to ISS operations. With the loss of *Columbia,* we now have only three remaining orbiters to conduct these operations through at least 2012 [and possibly much later, because (a) the OSP is likely to encounter development problems that will delay its initial operational date and (b), as I will discuss later, Shuttle capability will be needed even after a successful OSP system is deployed]. Moreover, with this extended operational period, as I mentioned earlier, the likelihood of another Shuttle failure cannot be ignored. One key capability that ought to be explored in the SLEP (I don't know if NASA is planning this) is conversion of at least some missions to fully automated flight operations. More on this later.

Orbital Space Plane

Now, the OSP. In effect, the OSP and its expendable launch vehicle have been moved chronologically ahead of the Generation-2 program in NASA's original SLI; that is, development of technologies for, and selection of, a reusable system that was to have replaced the Shuttle's function of carrying crew and cargo to and from the ISS at lower cost and with higher reliability. Elements of the old Gen-2 program now appear in the NGLT array of system applications, but the new plan postpones a decision on developing an RLV to 2009—well into the development phase of the OSP. The OSP also replaces the function of the original CRV that was canceled in 2001, as I've noted earlier.

So, does the proposed OSP/Evolved Expendable Launch Vehicle (EELV) architecture meet these needs of NASA's?

If we assume successful, on-time development of the OSP, that architecture does indeed meet those needs (except that the proposed initiation date for crew return capability [no later than 2010] is four years beyond the Russian commitment to provide that capability).

But that's a big "if." Let's look at the background.

X–33. NASA's termination of the X–33 single-stage-to-orbit technology demonstrator was certainly a correct decision (although as I told this subcommittee on April 10, 2000, I really regret the expenditure of over $1 billion and several years on a program that, like the National Aerospace Plane, was doomed to failure by its overambitious goals right from the beginning).

Space Launch Initiative (SLI). NASA's subsequent decision to focus on a much more realistic two-stage-to-orbit architecture for the original SLI was also a wise one. As mentioned earlier, NASA has proposed to continue the evaluation of a reusable hydrocarbon-fueled first stage in the NGLT program, with significant cooperation from DOD. This evaluation could have some effect on the OSP development, in that the new ISTP proposal identifies the possibility of "OSP bridge to a new launcher" in 2016, but its major influence will be on the future (2009) NASA decision regarding a reusable booster. Contrary to NASA's and the DOD National Aerospace Initiative's focus on a hydrocarbon-fueled first stage, however, as I mentioned earlier, the Air Force Scientific Advisory Board's Summer Hypersonics Study in 2000 concluded that a hydrogen-fueled first stage, whether rocket-powered or airbreathing, is better than a hydrocarbon-fueled one. Hence consideration of hydrogen-fueled boosters should not be dropped from the NGLT.

Reusability. NASA should not, however, be blamed for postponing to 2009 a decision on development of a reusable launch system. The basis for that decision was sound: neither the commercial launch market nor the government launch market, even in combination, can support the estimated price tag of a new reusable launcher. Fortunately, while NASA was obeying the August 1994 Presidential directive to spend its time and money pursuing a too-ambitious reusable launch concept, the Air Force and its EELV contractors were able to develop two new expendable launcher families that now open up real possibilities to help solve NASA's near-term needs.

OSP/EELV Suitability. Back to the big "if." First, although the EELV program has demonstrated highly successful initial launches, it is still too early to tell if the EELVs can reliably support a major ongoing NASA requirement such as is posed by the ISS. The prospects are certainly good, and having two widely different vehicles rather than a single one is definitely a "plus." I'll return to this point later. Next, the OSP itself isn't even a "paper" vehicle yet. Although NASA has stated that it will be based on low-risk, current or near-current technology, we won't be able to evaluate its risk until there is better system and subsystem definition. Again, the concept makes good sense, but there is still much to be determined before one could place a soundly based bet on its success. NASA's record for on-budget, on-schedule development of new space transportation systems leaves some doubt as to whether the OSP will really become available on the proposed dates.

Cost. One troubling fact is the current OSP development cost estimate, which, although admittedly premature, ranges from $9 billion to $13 billion. Whatever happened to the $1.2 billion CRV, which was to have performed at least one of the OSP's missions—and the much more critical one at that, in terms of near-term ISS needs? NASA might be better off to focus solely at first on the ISS crew rescue requirement, which is urgently needed both to succeed the Russian Soyuz commitment beyond 2006 and to increase the size of the ISS crew to a viable complement, and put off adding the ISS access function (for both crew and cargo) until the OSP can demonstrate its ability to meet this first milestone. Certainly planning for the access function can begin, but it might make budgetary sense to conduct OSP development in an evolutionary manner, one step at a time, starting with the most critical ISS need. I will discuss this later.

Commercial Launch System Support

One further point on the ISTP: the original Gen-2 program in the ISTP was also to have provided the technology basis and risk reduction for a new reusable launcher that could begin to serve the entire space launch market—commercial, civil, and military—by the end of this decade. The OSP/EELV does not do that, and the new NGLT postpones possible RLV risk-reduction efforts to 2004–2009. In essence, NASA has proposed to delay its responsibility for risk reduction of low-cost reusable launch systems to succeed the EELV and the Shuttle, postponing any decision on proceeding with RLV development until 2009 at best. Indeed, if conditions such as the commercial launch market, DOD interest, and budget concerns at that time are not suitable, NASA may simply choose to put off *any* consideration of reusable launch-system development until longer-term NGLT program efforts are able to reset the stage. This would leave the U.S. launch industry with only the two EELV families for large-payload service.

Summary. In short, the revised ISTP is neither overly optimistic nor overly conservative. It is soundly based and should be supported. NASA's thinking in proposing the new OSP/EELV architecture as a second source to the Shuttle for access to and from the ISS does make sense. However, it is too early to assess the risk involved in implementing OSP development or the soundness of its cost estimates.

The highest risk in the OSP element of the ISTP is in the budget and schedule for full-scale OSP development to meet both the crew rescue and ISS transport functions. The highest risks in the NGLT element of the ISTP are (a) postponing RLV risk reduction research to support a go-no go decision in 2009, (b) over-emphasis on hydrocarbon-fueled first stage designs rather than a mix that includes hydrogen-fueled concepts, and (c) the reduced emphasis on advanced expansion-cycle rocket-powered launch systems. The highest risk in the SLEP element of the ISTP is the ability to provide crew safety for all flight modes over an extended period of operations.

To reduce these risks, I recommend (1) an evolutionary approach to OSP development, focusing first on the ISS crew return requirement and then on the transport function; (2) inclusion of hydrogen-fueled first-stage designs and expansion-cycle rocket technology development in the NGLT program, and (3) including in the SLEP (a) a method for reducing the Shuttle crew to four and designing the flight deck as an escape capsule for all flight modes, (b) providing an on-orbit thermal-protection-system inspection and repair capability, and (c) equipping the orbiters for optional fully autonomous operation.

Further considerations are discussed in my response to your subsequent questions.

(3) How might the OSP alter NASA's reliance on, and the flight rate of the Space Shuttle? Should crew and cargo delivery be addressed by separate systems? If the OSP and a separate cargo delivery capability for logistics re-supply were developed, would it be necessary to continue to fly the Space Shuttle? If so, what missions could not be accomplished without the Space Shuttle? If the Shuttle is required for the duration of the Space Station, is an OSP that performs both crew rescue and crew transportation required?

NASA's Needs

Assuming the OSP/EELV architecture is demonstrated successfully by the proposed date of 2012, it is again necessary first to project NASA's needs for space transportation at that time. Those needs will continue to fall into two categories: robot spacecraft missions and those involving human crews. The latter category, at least for the foreseeable future, is almost wholly focused on servicing the ISS. Robot spacecraft will almost certainly continue to be launched primarily by ELVs, including EELVs for the more demanding missions. Hence the primary motivation for continuing Shuttle operations after the (assumed) initial successful operation of the OSP is its role in servicing the ISS.

Rationale for Continuing Shuttle Operations

There is one overriding reason for NASA to maintain the ability to conduct Shuttle fleet operations even if the OSP is initially successful. Space transportation will remain a high-risk activity for the foreseeable future, so reliance on a single system for ISS servicing (the OSP/EELV) could once more precipitate a crisis much like the present one should the OSP/EELV system fail or otherwise be grounded for an extended period. In simple terms, maintaining a viable second source of access to the ISS ensures its continued operation in the event of a launch system failure. The Russian and European access capabilities could conceivably help to ameliorate this need, but neither can be counted upon, and even if NASA were to resurrect the Alternate Access to Station program, its designs could be a useful supplement, but not the primary ISS delivery system.

Other subsidiary reasons for maintaining Shuttle operational capability are:

(1) It may become necessary to replace one or more of the major ISS elements (e.g., a solar-panel wing), which cannot be carried by any conceivable OSP design;

(2) The sensitive economic situation in Russia (and also conditions in Europe) may deteriorate even further, so that reliance on Soyuz, Progress, and ATV for auxiliary ISS support may become impractical or impossible; and

(3) The Shuttle can provide services and facilities to the ISS that would not be available from an OSP; e.g., extra crew members for major repairs or replacement operations and to help conduct science experiments, water from Shuttle fuel cells, auxiliary equipment for short-term use on ISS research experiments, greater cargo capacity both up and down, etc.

NASA has also pointed out that with an operational OSP the Shuttle could focus on cargo missions to ISS, especially an automated version (discussed later), and could serve as a heavy lifter for future space exploration missions.

The only real negative, of course, is a big one: the additional cost of maintaining the Shuttle fleet in operational status. With a successful OSP available, the Shuttle could be pared down to perhaps one or two flights per year, and possibly even be maintained on a standby basis, flying only when its special capabilities are needed. However, not only would that raise safety concerns, but it doesn't reduce the required Shuttle infrastructure, which absorbs the bulk of Shuttle manpower and costs.

The safety issue could be somewhat ameliorated by having the Shuttle SLEP program explore reducing the number of crew members and providing the Shuttle with a suitable flight-deck escape capsule, which has been estimated to double the probability of crew survival. The best way to address both cost and safety issues of maintaining Shuttle capability, however, would be to equip the orbiters for fully autonomous operation, including automated docking at the ISS, as the Progress modules now do, and autonomous landings, as the old Soviet Buran did. For those missions in which a crew is needed at the ISS, they could be carried as passengers, as is planned for the OSP.

However, the real justification for continuing Shuttle operations is that the optimum implementation plan for the OSP would be an evolutionary one, as I will discuss later. Hence the Shuttle would be needed at least until the phased implementation of the OSP has been completed. The annual cost impact of Shuttle plus OSP for the next decade under such a plan needs to be established, of course, but the prospect of automating the Shuttle could conceivably reduce that impact, along with annual OSP evolutionary development budgets that are likely to be lower than the annual cost of implementing a fully capable OSP by 2012, if the present high OSP development cost estimates are to be believed.

Costs subsequent to 2012 are wholly dependent on the operating cost of the OSP/EELV architecture, which has yet to be even estimated, plus the cost of maintaining the Shuttles in flight-ready condition. Again, the operating cost benefits of a fully autonomous Shuttle should be factored into any trade study of parallel *vs.* serial OSP development, as should all viable alternatives such as dependence on Russian, European, and commercial transport capabilities for both crew and cargo. But until NASA has some idea of the OSP/EELV operating cost, it does not make sense to commit to a full OSP developmental effort aimed at complete Shuttle replacement as soon as the OSP becomes operational.

Summary. In short, both the Shuttle and the OSP (or an equivalent Shuttle substitute) are required for assured access to, and egress from, the ISS. Second-level design requirements for the OSP could focus on either a common vehicle for both crew and cargo or, more likely, different versions having a common technology base. The Shuttle SLEP should include autonomous operation of the Shuttle for cargo functions and possibly also for ferrying crews to and from the ISS.

(4) Given that the OSP program has not yet progressed beyond establishing the Level I requirements, do you think NASA's plan for spending approximately $750 million on technology demonstrations between FY03 and FY06 is justified? What technologies are the most critical to demonstrate before proceeding to full-scale development?

The primary risk-reduction measure in mission assurance is elimination of single-point failure modes, which is best accomplished by a combination of heritage technologies, proven integrated system health-management techniques, and redundancy, substantiated by test or demonstration and other means of independent verification. A flight demonstration is by far the most effective mission assurance tool. Hence the planned X–37 demonstration program would be highly valuable to OSP development, provided it does indeed address the critical technologies NASA has identified. These include, among others, the thermal protection system; an autonomous, fast-response flight control system; an integrated health-management system, preferably embedded in an fault-tolerant vehicle architecture; and a crew rescue system. The proposed Demonstration of Autonomous Rendezvous Technology (DART) and pad-abort demonstrations are also of high value to OSP development.

It will not be easy to establish which of these technologies are mandatory, to what level of development they need to be brought, the level of development risk, and whether they are consistent with cost goals and OSP operational objectives.

Note that it is not necessary for NASA to wait until the X–37 technology demonstration program is complete before initiating OSP development, especially if the phased development approach I have suggested is used. [Indeed, the NASA plan calls for full-scale development of the OSP to begin in 2004, long before the scheduled completion of X–37 orbital testing]. However, in contrast to Shuttle development, the OSP development program should be structured so that useful technologies and processes demonstrated by the X–37 and the other planned demonstration programs can be readily inserted; i.e., the program should be "drop-in friendly" for new technologies. Again, this is best accomplished via a phased OSP development program.

(5) What design alternatives should NASA examine as it performs its concept studies for the OSP? What changes to the OSP program would you recommend to reduce the cost or accelerate the schedule?

Conceptual Designs

NASA has already suggested that the design trade space for the OSP is essentially open; that is, it could be one or more reusable winged vehicles with passive or active thermal protection and powered or unpowered landing capability, or one or more expendable capsules employing ablative heat shields much like the Apollo capsule, or anything in between. Specific design options must await the formulation of second-level requirements; e.g., mass and dimensions of payload facilities; propulsion and power requirements; the nature of required medical care equipment and supplies; life-support requirements; integrated vehicle health-management system needs; ground facilities; crew escape system requirements; ISS docking, interface, and separation requirements; etc.

Design Approach

NASA level-1 requirements specify that the OSP system must accommodate both rescue and transportation capability for no less than four crew members, although different versions of the system design might be used to perform these two functions. The rescue function must be available no later than 2010; the transport function no later than 2012. NASA's current proposal suggests that development of both functions be implemented in parallel, at an (admittedly premature) estimated cost of $9–$13 billion. In the interest of reducing that cost, or at least stretching it out over a longer period to minimize the annual budget impact, it would seem to make sense to develop the required OSP functions serially rather than in parallel.

The urgent need is for ISS crew rescue (which is actually needed by 2006 rather than the specified 2010, in view of the end of Russia's commitment to provide Soyuz lifeboats for ISS). Why not seek the lowest-cost design approach to meet that requirement and then use the technologies demonstrated and experience gained during that development to develop the transportation capability? There are at least two viable low-cost design options for crew rescue: the original CRV concept and an expendable (or partly reusable) capsule with an ablative heat shield. Other options for use of modified experimental vehicles are discussed below.

Although it might turn out that the transportation capability might indeed require different design features than the rescue capability, NASA should at the very least conduct trade studies on the parallel and serial design approaches before committing to full-scale development.

This evolutionary development option, as well as NASA's proposed plan, requires an operational Shuttle fleet until the OSP transport function is demonstrated, so the trade study comparing the two approaches should include the Shuttle SLEP options I mentioned earlier, such as fully autonomous operation and a crew escape system. Also implicit in this trade study would be the viability of some means for persuading Russia to extend its Soyuz lifeboat commitment beyond 2006.

In conducting this (and other) trade studies NASA faces the challenge of "requirements creep;" that is, allowing requirements for technical demonstration of the transport phase to affect low-cost rescue options. NASA needs to re-establish cost credibility, and a properly phased, evolutionary program has the potential to do that.

Other Trade Studies. Other trade studies that should be conducted before proceeding to full-scale OSP development include the following:

Basing a Shuttle at the ISS. A temporary cost-saving option that should be explored is to extend the on-orbit lifetime of some of the Shuttle fleet so as to allow an orbiter to remain at the ISS for extended periods, thereby serving both functions required of the OSP. This approach has obvious disadvantages; i.e., it only postpones the requirement for a Shuttle replacement or supplement such as the OSP; it reduces Shuttle operational availability by keeping a third of the remaining fleet inactive for long periods; and it exacerbates the disruption that would occur following another Shuttle loss.

However, it would remove the time pressure on OSP development, especially the 2006 deadline for ISS crew rescue capability, and the presence of the Shuttle crew along with that of the ISS would provide full crew capability for both ISS maintenance and science research; e.g., 10 crew members (or 7, if the SLEP program recommends reducing the Shuttle crew to 4 so as to facilitate crew escape). Also, NASA could reconsider its decision to cancel the low-budget Alternate Access to Station program, whose designs could be evaluated for their ability to supplement ISS cargo transport requirements in lieu of more frequent Shuttle deliveries, especially after Russia ceases Progress flights.

Replacing Shuttle *Columbia*. Another temporary cost-saving option that should be evaluated is simply replacing *Columbia.* A four-orbiter fleet, especially if augmented by the Shuttle SLEP, would significantly ameliorate the disadvantages of basing a Shuttle at the ISS. Even if the ISS-based Shuttle option is not pursued, a four-orbiter fleet could allow development of the OSP transportation function to be stretched, relieving the time pressure (and annual budget impact) somewhat. However, without an ISS-based Shuttle the four-orbiter fleet would not resolve the crew rescue function or enable a full crew to occupy the ISS when a Shuttle is not docked to the station. Hence the crew return function for the OSP would still be needed by 2006.

Use of Modified Experimental Vehicles. Modifications that would be needed by the X–37 technology demonstrator or the Air Force's Orbital Maneuvering Vehicle (OMV) should be costed and evaluated for potential risks as interim solutions to each of the two OSP functions, including the use of multiple vehicles to accommodate the 4-person minimum requirement. Should either provide significant cost reductions *vs.* the OSP without introducing unacceptable risk, this option could reduce the pressure on near-term OSP development. Note, however, that the cost of incorporating a crew compartment could turn out to be prohibitive, even for multiple vehicles.

Other experimental vehicles that could be evaluated for the cost and risk of performing part or all of the OSP function would be NASA's HL–20 and X–38 or the Air Force's X–24C. The Air Force has also contemplated developing a generic transatmospheric vehicle, which could be considered as a potential means for augmenting OSP functions.

Evaluation of Apollo-type Systems for both Crew Return and ISS Transport. A top-level assessment of this approach, completed in March 2003, suggests that it might be the lowest-cost option to meet OSP requirements in the shortest time, especially if development of return and transport capabilities were to be conducted serially, as I have suggested. The initial assessment report states, "The (assessment) team concluded unanimously that an Apollo-derived CRV (crew return vehicle) concept appears to have the potential of meeting most of the OSP CRV Level-1 requirements. An Apollo-derived CTV (crew transport vehicle) would also appear to be able to meet most of the OSP Level-1 CTV requirements with the addition of a service module." This option clearly needs to be evaluated in further detail.

(6) How does the decision to proceed with a design that is totally reusable, partially reusable, or expendable drive design complexity, development schedule, cost, and safety?

Reusability almost certainly implies increased design complexity, a longer development schedule, and increased development cost. The effect of reusability on safety, vis-à-vis expendable systems, has yet to be evaluated. Also, increasing the degree of reusability may or may not reduce operational costs, depending on specific design attributes. It is possible that reusability will, in the long-term, prove to be a valuable attribute in terms of operating cost, turnaround time, and reliability, but there is as yet no evidence to support its nearer-term benefit. The often-cited concept of "aircraft-like" operations to realize these benefits requires a full understanding of what is meant by "aircraft-like." Airplanes are basically designed for cruise conditions while space launch vehicles are designed solely as accelerators. Comparing them without defining the basis of comparison is not realistic.

(7) Can the OSP schedule be accelerated significantly without introducing unwarranted risks? If so, what recommendations do you have?

Once the Shuttle fleet returns to flight status, the urgent need is for crew return capability from the ISS. The evolutionary OSP development program I have suggested would accomplish this goal at the earliest possible time with low risk. The transport capability is not urgently needed as long as the Shuttle fleet is operational, and hence could be developed according to NASA's proposed schedule, or even stretched out somewhat to reduce both risk and annual budget impact,

(8) What challenges may NASA face in using an Expendable Launch Vehicle (ELV) as the boost vehicle for the OSP? Does the use of an ELV for human space flight pose an unacceptable risk?

Safety. The primary challenge is, of course, safety, but that is true for any launch system, not just expendables. The current failure rate (loss of mission) of the partly reusable Shuttle is now 2 in 114, or about 1.75 percent. The current failure rate of the Delta-2 ELV is 3 in 125, or about 2.4 percent and of the Atlas 2–5 ELV family (including 2A, 2AS, 3A, 3B, and 5) is zero in 64. (That is formally 0 percent, which is meaningless, but note that the Atlas-5 design failure rate is 0.45 percent compared with the Atlas-2AS *design* failure rate of 1.28 percent, with zero actual failures).

Single-point-failure tolerance is the key factor in launch-vehicle mission assurance. At least one of the EELV systems, the Atlas-5, is claimed to have full single-point-failure tolerance with the exception of its two main engines, the RD–180 first-stage engine and the RL–10 upper-stage engine. However, the RD–180 is probably the most robust large rocket engine ever built (its Russian designers claim it is even reusable), and the RL–10 has proven its robustness over 40 years of operations. Moreover, for components such as engines that are not subject to safe redundancy management, the use of "safe-life" designs and criteria can be implemented, as is common practice for aircraft jet engines (i.e., ground testing to certify design margins with appropriate safety margins). Finally, there are design options for the heavy-lift EELVs which provide engine-out redundancy that would eliminate even these single-point failure modes.

Note that any residual safety risk imposed by using an ELV can (and should) be ameliorated by incorporating an effective crew escape system in the OSP. Such a system (which may turn out to be the whole OSP itself) is likely to be specified in the second-level OSP requirements.

Hence safety *is* a challenge, but the risk of flying people on an ELV is certainly not unacceptable compared with the partly reusable Shuttle. Also note that the Russian Soyuz launcher, upon which we now rely for all crew-carrying operations to and from the ISS, is expendable, as were the Atlas, Titan, and Saturn rockets used for the Mercury, Gemini, and Apollo programs without a single launch failure.

Recurring Cost. A second potential challenge in using ELVs is the recurring cost per launch (after all, cost reduction was the prime motivation for developing the Shuttle and for creating the X–33 program and the original ISTP). Current estimated launch cost levels released by the Air Force's EELV System Project Office range from $80 million for the MLV models to $150 million for the HLV models.

Although these costs could certainly increase if any special provisions need to be incorporated for OSP operations (e.g., human-rating, if NASA decides not to rely wholly on the OSP crew-escape system), the EELV cost range remains well within the Shuttle's cost-per-launch envelope.

Booster availability. A third, although lesser, challenge is booster availability. Having two widely different EELV families rather than a single one is definitely a "plus" in avoiding major downtime problems, although there are some cost implications (fortunately not major ones) associated with ensuring OSP compatibility with both families. It will also be necessary to coordinate launch manifesting of the EELV systems with both military and commercial customer demands, but this has never been a serious problem with prior ELV families.

Flight Control Issues. If the OSP design turns out to be a lifting-body or winged configuration, adequate control authority of the EELV booster during transonic flight could become an issue, especially if NASA's current plan to launch the X–37 technology demonstrator inside a fairing is pursued. The Titan vehicle that was to be used to launch DynaSoar back in the 1960s required the addition of fins for the necessary control authority and a strengthened structure to accommodate higher bending moments. If the EELVs will require comparable "fixes," there will be cost and schedule implications, which could be exacerbated if no information is available from an encapsulated X–37 flight demonstration. If the OSP design ends up as a ballistic Apollo-like capsule, there will be cross-range restrictions on the return-to-Earth launch window.

That completes my answers to the questions posed in your invitation. However, I have a recommendation for the scenario that NASA should pursue for optimum servicing of the ISS through the completion of its mission, which is estimated to be 2020–2025.

The first task, of course, is to resolve the issues surrounding the failure of *Columbia* and return the three remaining orbiters to service as soon as possible without prejudicing crew safety.

The Shuttle SLEP effort should be initiated immediately, and should include the following elements, to be implemented as soon as possible without excessive disruption of service to the ISS: (1) Converting the 4-person flight deck to an escape capsule suitable for egress during all flight modes; (2) Providing the orbiters with the option for fully autonomous operation; (3) Providing a method for inspecting and, if necessary, repairing the thermal protection system on orbit; and (4) Equipping two orbiters for orbital stays of at least four months. Depending on the availability of adequate budget resources, a replacement could be built for *Columbia.* Note that during this period, we will continue to rely, to the same degree as prior to *Columbia*'s failure, on Russian Soyuz and Progress flights and possibly the European ATV.

As soon as one orbiter is equipped for long-term stays on orbit (which should be prior to 2006), that orbiter should be flown to the ISS and based there for four or more months. Until the OSP crew-return version has been demonstrated, the two orbiters suitably equipped should continue to provide that capability, alternating with each other.

Meanwhile, the NGLT program should be pursued and trade studies followed by evolutionary development of the OSP should be conducted, beginning with the crew return function and subsequently proceeding to the crew transport (and possibly cargo transport) functions. (Pending results of the design trade studies, of course, the lowest-cost, nearest-term option is likely to turn out to be an Apollo-derived design). OSP flights to the ISS should begin as soon as the crew return function has been demonstrated, relieving the Shuttles of the need for on-orbit stays.

When the OSP transport function has been demonstrated, the Shuttles should be placed on a standby basis for autonomous operation, to fly if and when needed for lifting large payloads to the ISS, for crew-carrying and cargo-carrying during any OSP standdown, and also for ambitious NASA science and exploration missions in the Solar System.

BIOGRAPHY FOR JERRY GREY

Director, Science and Technology Policy

Dr. Grey received his Bachelor's degree in Mechanical Engineering and his Master's in Engineering Physics from Cornell University; his Ph.D. in Aeronautics and Mathematics from the California Institute of Technology.

He was Instructor in thermodynamics at Cornell, engine development engineer at Fairchild, Senior Engineer at Marquardt, and hypersonic aerodynamicist at the GALCIT 5-inch hypersonic wind tunnel. He was a professor in Princeton University's Department of Aerospace and Mechanical Sciences for 17 years, where he taught courses in fluid dynamics, jet and rocket propulsion, and nuclear power plants and served as Director of the Nuclear Propulsion Research Laboratory. He was President of the Greyrad Corporation from 1959 to 1971, Adjunct Professor of Environmental Science at Long Island University from 1976 to 1982, and Publisher of *Aerospace America* from 1982 to 1987. He is now Director, Science and Technology Policy for the American Institute of Aeronautics and Astronautics, Editor-at-Large of *Aerospace America,* member of the Universities Space Research Association's Science Advisory Panel for the NASA Institute for Advanced Concepts, consultant to a number of government and commercial organizations, and Visiting Professor of Mechanical and Aerospace Engineering at Princeton.

Dr. Grey is the author of twenty books and over 400 technical papers in the fields of space technology, space transportation, fluid dynamics, aerospace policy, solar and nuclear energy, spacecraft and aircraft propulsion, power generation and conversion, plasma diagnostics, instrumentation, and the applications of technology. He has served as consultant to the U.S. Congress (as Chairman of the Office of Technology Assessment's Solar Advisory Panel and several space advisory panels), the United Nations (as Deputy Secretary-General of the Second UN Conference on the Exploration and Peaceful Uses of Outer Space in 1982), NASA (as a member of the NASA Advisory Council), the Department of Transportation (as Vice Chairman of the Commercial Space Transportation Advisory Committee), the Department of Energy (as a member of the Secretary of Energy Advisory Board), and the U.S. Air Force, as well as over thirty industrial organizations and laboratories. He was Vice President, Publications of the AIAA, Chairman of the Coordinating Committee on Energy of the American Association of Engineering Societies, a Director of the Scientists Institute for Public Information, Vice President of the International Academy of Astronautics, and President of the International Astronautical Federation.

He is listed in over twenty biographical publications, and has received national awards from the Aviation/Space Writers Association and the American Astronautical Society.

1801 Alexander Bell Drive, Suite 500, Reston, VA 20191–4344; Phone: 703–264–7500; Fax: 703–264–7551; Website: http://www.aiaa.org

Chairman ROHRABACHER. Thank you very much. Our next witness is Dale Myers and a former Deputy Administrator for NASA back in the 1980's. We welcome Mr. Myers and any illumination that you might provide us today.

STATEMENT OF THE HONORABLE DALE D. MYERS, PRESIDENT, DALE MYERS AND ASSOCIATES

Mr. MYERS. Thank you, Mr. Chairman, and Members of the Committee. I was asked by the Chairman to review a short study that was done to determine the feasibility of using the Apollo Command Module for a Crew Return Vehicle from the Space Station and for a Crew Transfer Vehicle and then to answer some questions that the Chairman has asked.

The Team, with over 150 years of space design and operations experience, five guys, has had hands-on design, manufacturing, and flight experience with spacecraft hardware. We had John Young on the committee, who is the astronaut that first flew the Shuttle and has, for many years, had a safety responsibility at the Johnson Space Center, Vance Brand, who flew the Apollo Soyuz Program, so he became aware of all of the design functions of the Soyuz Program. We really had a pretty great bunch of guys looking at this background of whether the Command Module would make sense as a CRV.

The Team unanimously concluded that a four- to six-person Command Module with a retrorocket attached to it would meet most of the Level 1 requirements for the CRV—for the Crew Return Vehicle of the OSP. Replacing the retrorocket with a more powerful Service Module, a Command and Service Module would meet most of the Level 1 requirements for a Crew Transfer Vehicle. It was further agreed that a CRV/CTV looked attractive enough that it should be studied thoroughly to compare its cost, schedule, and safety and other advantages and disadvantages relative to the other configurations being considered for OSP. The Team concluded that existing Command Modules would not be safely used—could not be safely used because of water immersion, lack of traceability, and obsolescence and age of the equipment.

We visualize using the outer mold line of the Apollo Command Module, that is the outer shape of the Command Module, so that the launch escape system could be replicated and the tremendous heritage of the Apollo would be directly applicable in the aerodynamics, thermal protection, and reaction control systems, couch placement, and the general configuration of the design. The microfiche drawings that are available from the Command Module and the specs and the myriad technical reports would blaze a trail for the designers even though all of the hardware would probably be new or replicated. Even the Command Module structure would be new, because the Command Module would have to withstand 15 pounds per square inch internally to be compatible with the ISS. It was designed for 5 psi for the Apollo program.

There was not full agreement by the Team as to the value of the existing drawings in reducing costs and schedules, but the Team did unanimously agree that a CRV would be much less expensive than any other configuration that we could visualize. And a CRV/CTV, in other words Command—Crew Return Vehicle combined with a Crew Transfer Vehicle, would be less expensive than a winged vehicle.

Operations is another matter. The Command Module Crew Return Vehicle with just a retrorocket to re-entry would require many landing sites to meet the Level 1 requirement of making medical-specific facilities available within a 24-hour period. With a Service Module, smaller than the Service Module of Apollo, but a powerful Service Module added, we anticipate a major reduction in landing sites and expect the life cycle costs to be attractive. Water landings are not a great environment for ill or injured crew members, although I will admit it is better than nothing.

The Team recommended a serious study of land landing systems for capsules with a powerful Service Module—excuse me, for the capsules. With a powerful Service Module and land landing, it would surmise that life cycle costs would be very attractive. We guessed that a combination Command and Service Module Crew Return Vehicle and Crew Transfer Vehicle could become operational in six to seven years or less from Phase A with proper funding.

In the interest of time, I have answered some of the Chairman's questions in my written testimony, and I suggest that I respond to questions.

[The prepared statement of Mr. Myers follows:]

PREPARED STATEMENT OF DALE D. MYERS

A team (Appendix 1) was chartered by NASA to make a top-level assessment of the viability of using the Apollo Command and Service Modules (CSM) as the basis for a Crew Return Vehicle (CRV), and potentially for a Crew Transfer Vehicle (CTV) for the International Space Station (ISS). This assessment was conducted on March

13–14, 2003. None of the conclusions can be other than judgmental, due to the short time of study, but this small group does cover a broad background of knowledge and experience about Apollo and about human space flight.

Major Conclusions

The Team concluded unanimously that an Apollo-derived Crew Return Vehicle (CRV) concept, with a 4- to 6-person crew, appears to have the potential of meeting most of the OSP CRV Level 1 requirements. An Apollo derived Crew Transport Vehicle (CTV) would also appear to be able to meet most of the OSP CTV Level 1 requirements with the addition of a service module. The team also surmised that there would be an option to consider the Apollo CSM concept for a common CRV/CTV system.

It was further concluded that using the Apollo Command Module (CM) and Service Module (SM) as an ISS CRV and CTV has sufficient merit to warrant a serious detailed study of the performance, cost, and schedule for this approach, in comparison with other OSP approaches, to the same Level 1 requirements.

Cost and Schedule

It was not possible for the team to make an estimate of the cost of the design, development, manufacturing and operational costs. On the one hand, the Apollo system is well understood, and proved to be a highly successful, rugged system with a very capable launch abort system. Documentation would be very helpful in leading the designers. On the other hand, nearly every system would have to be redesigned, even if it were to be replicated. None of the existing hardware (such as CMs in Museums) was thought to be usable, because of age, obsolescence, lack of traceability, and water immersion. There would be no need for fuel cells or cryogenics, and modern guidance and communications would be lighter and less expensive.

There was not full agreement on the cost benefit of using existing Apollo documentation in the design of, what was agreed would be, a new vehicle with all new subsystems. However, it was judged that the development and manufacturing costs of an Apollo derived CRV has the potential of lower cost than a winged vehicle due to its lower complexity level.

The Operational costs would be high for a Command Module Crew Return Vehicle (CM/CRV). Because of the very low orbital delta V and the low aerodynamic crossrange, many landing sites would be required and the infrastructure for 24 hour, seven day operations would be expensive, particularly to meet the Level 1 requirement to bring the astronauts to medical care in 24 hours. By adding a Service Module, orbital delta V would make it possible to reduce dramatically the landing sites required. This is why the team surmised that a Command and Service Module Crew Return and Crew Transport Vehicle (CSM/CRV/CTV) looked attractive.

The team judged that a schedule for the CRV of 4–6 years (from contract go-ahead) and 5–7 years for the CTV or a CRV/CTV (from contract go-ahead) would be reasonable.

Other Considerations

Although the flight hardware would be less expensive, and its impact on the Expendable Launch Vehicles would be minimal (it's just another axisymmetrical payload), the landing sites for the CRV may drive the Life Cycle costs high. By adding a Service Module (smaller than the one required to go to the moon), orbital crossrange of 3000 to 5000 ft/sec, might be gained, and the number of landing sites radically reduced. If land landings can be added to the system safely, another major reduction in life cycle costs would result, because the team believed that the system could be made re-usable.

Some Personal Thoughts

Although the team was not asked to compare the capsules to winged vehicles, and we did not, I have some comments relative to wings vs. capsules.

The Apollo Program never had a parachute failure in operation, although we had failures during the test program. We had one parachute fail due to N_2O_4 leaking onto the shrouds, but the vehicle landed safely on two parachutes.

The Shuttle has had a wing failure, but the failure was apparently caused by the foam insulation from the tank. Shuttle runway landings have been 100 percent successful.

It appears to me that the robust launch escape system of Apollo, which worked over a wide range from the launch pad to high altitude, will be hard to beat in a winged vehicle.

This Apollo based system, without aerodynamic controls, wings, and landing gear is clearly simpler.

The ablative replaceable heatshield is simpler to build and install than the corresponding winged vehicle thermal protection system. We already know the thermal distribution on the vehicle. With a land landing, a reusable heatshield might apply to the Apollo system.

A land landing is a new development for a Command Module and not an easy one. With a five-man crew, three parachutes (as proven on Apollo) or a parasail might be used (although I'm not sold on parasail reliability, and wonder how redundancy is supplied). Close to the ground, a retrorocket could be used, with a blowout hatch in the heat shield to expose the rocket. Alternately, air bags could absorb the vertical landing velocity. Any of the means of softening the land landing could be aided with crushable struts on the couches. I am not familiar with the reliability record of the Russian land landing system, although I have heard that they have had trouble with it. Tumbling while landing in a crosswind is a threat.

Landing with wings yields good atmospheric cross-range, and thus more flexibility in when and where to land. The winged system may be more Life-Cycle Cost effective because of that feature, and it might give more safety because of its ability to land at other airports.

Winged vehicles have less "g-load" (gravity load) during re-entry, relieving stress on an injured or ill crew member.

If all things were equal, I'd choose winged vehicles. Unfortunately, they are not known to be equal, and that's why the team recommended a thorough study of the Apollo CM/SM as a CRV/CTV.

Comments on the NASA Integrated Space Transportation Program (ISTP)

The Chairman asked that I comment on some issues other than the Apollo CRV and CTV. These will be personal remarks, and not those of the Apollo CRV/CTV Team.

I support the ISTP. The OSP schedule looks reasonable, but only if funding is made available in a timely fashion. I'd like to see a strong effort in autonomous docking for either system, and in launch escape if a winged vehicle is chosen. For the Command Module CRV/CTV, development of a land landing system is the only major new technology, other than long duration storage in space. I can't really strongly recommend the land landing until a Life Cycle Cost Effectiveness study is completed. If earlier dates are strongly desired, I believe some time could be saved by accelerating Phase A and Phase B studies and initiating procurement of long lead time items just after Preliminary Design. Some increase in risk would result, but it appears that the contractors have already invested significant funds, and configurations are reasonably stabilized as compared to the Phase A and B of the Shuttle or Space Station. In the case of the Apollo combined CRV/CTV, I would consider giving the Service Module to a different contractor than the Command Module. Doing so might make it possible to do the Crew Transport Vehicle schedule in 4–6 years, and at the same time, stimulate new design at more than one contractor.

Using an Expendable Launch Vehicle for human transport is feasible, if the same attention is, or has been, given to the reliability design requirements for the ELV as NASA gives for human flight. The new Evolved Expendable Launch Vehicles (EELVs) have been designed for high reliability, and first flights look good. A robust launch escape system would reduce risk even further. A careful review of the EELVs would be needed to determine whether the NASA version would be common with the military and commercial EELV. If not, an additional expense is incurred, and less reliability advantage gained from the repeated launch of common ELVs for all launches.

The introduction of the CRV/CTV to be launched on Expendable Launch Vehicles (ELVs) will allow NASA to use the Shuttle for cargo for the ISS, to share with the OSP crew transport to the ISS, and for lower inclination orbits where heavy science payloads can be placed in orbit, maintained and upgraded, repaired, and serviced. Even if a logistics module were developed to be launched by an ELV, I firmly believe that the Shuttle will be needed until a second-generation manned launch vehicle is operational. The ISTP gives NASA more time to develop the technologies required to design a low cost to orbit launch vehicle.

A key factor that must be considered is this. Will the U.S., or the world decide to go back to the moon or Mars in the next 20 to 50 years? I'm sure space policy is dealing with that question, but assuming there is interest, we must continue low-level system studies and technology development, including nuclear rockets (unless and until something better comes along). An eventual plan to return to the moon would favor choosing a capsule approach for a CRV/CTV.

The greatest risk is doing nothing. NASA and industry management, engineers and manufacturing people are getting old, like me. A new hardware program is sorely needed to bring vibrant new people in to bear on NASA Programs. An OSP followed by a new low cost launch vehicle, followed by a phased return to the moon and Mars would be an ideal program that would bring stars to the eyes of every young American child and help rebuild American interest in engineering.

Appendix 1

Assessment Team Members

Vance Brand
Apollo Soyuz (ASTP) and Commander for STS–5, STS–41B, STS–35

Aaron Cohen
Former Director of NASA JSC; former Manager of the Command and Service Module in the Apollo Spacecraft Program Office; former Shuttle Orbiter Project Manager, responsible for design, development, production, and flight tests; former acting Deputy Administrator.

Dale Myers
Former V.P. and Program Manager—Apollo Command and Service Module, NAA/Rockwell; Former NASA Associate Administrator for Manned Space Flight; Former NASA Deputy Administrator

Kenneth Szalai
Former Director, NASA Dryden; Chief Engineer NASA F–8 DFBW with Apollo GNC systems. Team leader.

John Young
Gemini 3, Gemini 10 (CDR), Apollo 10, Apollo 16 (CDR), STS–1 (CDR), STS9 (CDR)

The Team convened 13–14 March 2003 to conduct the assessment.

BIOGRAPHY FOR DALE D. MYERS

President, Dale Myers and Associates, P.O. Box 232518, Encinitas, CA 92023; Tel. (760) 753–4043; Fax (760) 753–8796; E-mail: DaleMyers@cox.net

Education

B.S. Aeronautical Engineering, University of Washington, 1943

Employment/Experience

1989–present—President, Dale Myers and Associates, an Aerospace Consultancy

1986–1989—Deputy Administrator, NASA

1984–1986—President, Dale Myers and Associates

1979–1984—President, Jacobs Engineering Group, Pasadena, CA

1977–1979—Under Secretary, U.S. Department of Energy

1974–1977—Vice President, Rockwell International and President, North American Aircraft Group

1970–1974—Associate Administrator, Manned Space Flight, NASA

1964–1969—Vice President and Program Manager Apollo Command and Service Modules, North American Rockwell

1957–1964—Vice President and Program Manager, Hound Dog Air Launched Missile, North American Aviation

1943–1957—Aerodynamicist to Deputy Director, Aerophysics Department, North American Aviation

Affiliations/Activities

Member

Honorary Fellow, American Institute of Aeronautics and Astronautics

Fellow, American Astronautical Society

Sigma Alpha Epsilon (Chapter President, 1943)

National Academy of Engineering, 1974

California Chamber of Commerce, 1975–1977

Member, International Academy of Astronautics, 1991

Board of Directors

1992–1997—Board member, General Science Corporation

1989–1998—Board member, MacNeal Schwendler Corporation

1989–1994—Trustee, Logistics Management Institute

1984–1986—Board Member, SYS Technologies

1984–1986—Board Member, Aerovironment

1979–1984—Board Member, Jacobs Engineering Group

1974–1977—Board Member, Ducommun Corporation

Awards, Honors and Recognition

Honorary Doctorate Degree, Whitworth College, Spokane, WA 1971

NASA Distinguished Service Medal, 1971

NASA Distinguished Service Medal, 1974

Meritorious Service Award, Compton Schools, 1977

Achievement Award, Los Angeles City Schools, 1976

Department of Energy Distinguished Service Medal, 1979

Distinguished Alumnus, University of Washington, Department of Aeronautics and Astronautics, 1982

Aerospace Hall of Fame, Museum of Science and Industry, Los Angeles, CA

Who's Who in America, in American Politics, in Aviation, in Government, in Technology, in Finance and Industry

International Directory of Distinguished Leadership

Service

NACA Stability and Control Subcommittee, 1948–51

United Way, Chairman 2nd District, Los Angeles, 1983

NASA Advisory Committee, 1984–1986

American Delegate, AGARD, 1986–1989

Visiting Committee, University of Washington, 1990–1998
San Diego Fund Raising for University of Washington, 1990
Director, San Diego Aerospace Museum, 1993–present
NRC AF Study Board Committee on Pre-Milestone One, 1993
NASA Aeronautics Advisory Committee, 1994–1997
Visiting Committee, University of Washington Astronautics, 1998–present

Chairman ROHRABACHER. Yes, we have a few for you. All right.

Mr. MYERS. Thank you.

Chairman ROHRABACHER. Thank you very much. And our final witness is Dr. Michael Griffin, who is President and Chief Operating Officer of In-Q-Tel, an independent, non-profit venture group chartered to identify and invest in cutting edge commercial technologies. And would the private sector have something to contribute to this situation? You may proceed.

STATEMENT OF DR. MICHAEL D. GRIFFIN, PRESIDENT AND CHIEF OPERATING OFFICER, IN-Q-TEL.

Dr. GRIFFIN. Thank you. Thank you for inviting me to appear before this committee to discuss the NASA Orbital Space Plane Program and its relationship to the new NASA Integrated Space Transportation Plan. I will try in the next few minutes to summarize the key points offered in response to this committee's questions in my written testimony.

First, I believe there are more effective alternatives, both strategically and economically, than the OSP program with the Level 1 requirements as presently conceived. If OSP is intended only to support the International Space Station by supplementing the Shuttle, if continued use of the Shuttle is intrinsic to the ISTP, and if a viable Shuttle program requires several flights per year, then normal ISS support requirements can be met without the OSP.

Moreover, a vehicle meeting but not substantially exceeding the stated Level 1 requirements will have very limited capability to execute any mission beyond support of the ISS. The OSP will thus contribute only marginally to the Nation's overall space transportation architecture and should not be funded under such conditions. The OSP should be developed as part of and in concert with a more complete Integrated Space Transportation Plan. Such a plan should provide a road map with scheduled goals and funding requirements for development of robust and economical space transportation technology and systems from the small payload class up through heavy-lift capacity, sufficient to meet the needs of lunar and Mars exploration programs.

The International Space Station can best be supported over the next decade by, number one, making the minimally necessary Shuttle modifications to enable flights to ISS in the near-term. Two, restoring the alternate Access to Station Program thereby augmenting the capability to re-supply the ISS when the Shuttle system is temporarily grounded and helping to sponsor the commercial development of robust economic small and medium launch vehicles by providing a known and guaranteed government payload market. Three, developing an Orbital Space Plane along appropriate lines, taking into account the likely needs of future missions beyond the requirement to support ISS. Four, deliberately phasing out the Shuttle as the OSP becomes available. I offer this opinion reluctantly, because the Shuttle offers incredible capability, likely irreplaceable with any single vehicle or design. But despite our hopes during its design and development phase, the Shuttle has proven to be expensive to operate, cumbersome to maintain, logistically fragile, and technically unforgiving. It is time to move on.

International Space Station crew escape requirements are important, but should not drive the design of the OSP. Crew escape capability should be needed, at most, a few times over the working life of the ISS. Providing such capability should not be allowed to affect the routine operations of a transportation system. Should a new OSP be designed and built, it certainly makes sense to consider employing it as a Crew Return Vehicle, but its design should be governed by the requirements for crew transfer, not crew rescue.

A key feature of any integrated space transportation architecture must be the development of technology and flight systems for highly reusable, two-stage-to-orbit launch systems as rapidly as funding permits. We have seen that industry alone can not close the business case for such an effort, a feature characteristic of many large transportation infrastructure systems. But like the Nation's air traffic control network or interstate highway system, the benefits will in the long run, far outweigh the costs, and it is to exactly such projects that government investment should be allocated.

With that I conclude my oral statements and, as with the others, I am ready to take your questions. Thank you.

[The prepared statement of Dr. Griffin follows:]

PREPARED STATEMENT OF MICHAEL D. GRIFFIN

Abstract

Requirements for NASA's proposed Orbital Space Plane (OSP) and its place in the new Integrated Space Technology Plan (ISTP) are discussed. Consideration and adoption of appropriate top-level goals for the Nation's space transportation architecture is advocated. The role of OSP relative to the Space Shuttle in support of International Space Station (ISS) is treated. Key OSP design features, especially the issue of a winged vs. semiballistic vehicle design, are discussed. OSP programmatic assumptions are examined, with attention to cost, schedule, and technology development requirements.

Mr. Chairman:

Thank you for inviting me to appear before this committee to discuss this most important issue, that of the NASA Orbital Space Plane (OSP) program, and its relationship to the new NASA Integrated Space Transportation Plan (ISTP).

I will open by noting that, in my opinion, this is not only a most important topic for discussion, it is the *single most important* subject to be addressed by the Nation's leaders in connection with our nation's future in astronautics.

In aeronautics, the air is merely a medium through which one must transit in order to reach a desired destination. In astronautics, both air and space become navigable media, but space also becomes much more: It is itself a destination, a region offering access to an enhanced vantage point, hard vacuum, microgravity, advantageous positioning, and new sources of energy and materials.

But to use these assets we must first reach the destination. The physics of Earth's gravity well are such that once we reach low Earth orbit (LEO) we are, in Arthur C. Clarke's famous turn of phrase, "halfway to anywhere." This hearing, one of many such discussions on the topic, is *prima facie* evidence that despite the passage of sixty years since the invention of the first vehicles capable of reaching space, the task of reaching LEO—reliably, routinely, and cost-effectively—continues to elude us. We are still having trouble taking Clarke's first half-step.

The task is difficult. To reach LEO, we must package the energy required for an intercontinental aircraft flight in a container with the volumetric efficiency of an eggshell, yet which is tough enough to withstand high inertial, thermal, and aerodynamic loads. The stored energy must be expended within a few minutes, and prevented from being expended in a few seconds. Each launch of an expendable vehicle is its maiden flight, an event performed under only the most carefully controlled and limited conditions in aeronautics, yet which in astronautics must be a maximum performance event. A reusable vehicle must survive a return through an atmospheric flight regime so rigorous it cannot be simulated in even the highest performance wind tunnels; such a vehicle can be fully tested only by flying it "for real."

But while the task is difficult, we have allowed ourselves to make it more difficult than it need be. We have sometimes concentrated so heavily on particular details and "point designs" that we have failed to appreciate that each such design must blend into, and be part of, a broader architecture. We have sometimes become enamored of specific requirements, to the exclusion of broader goals. We have at times over-valued the role of government while failing to pay due attention to the skill and expertise residing in our industrial base. At other times we have done the opposite, leaving too much to the discretion of contractors who, after all, bear no final responsibility for the success or failure of any government enterprise. In some cases we have stayed too long with proven but inefficient technology. In other cases we have designated as "operational" those things which were, at best, operating at the very edge of the state of the art, and possibly beyond it. We accept, without serious objection, a "cost of doing business" in government space endeavors that should shame us all were it to be examined on any sort of rational basis.

We have made most of the mistakes that can be made, mistakes which would have put any commercial enterprise mercifully out of its misery, in favor of a competitor with a better approach. But because the development of space launch vehicles has been almost exclusively a government enterprise, and because the few and only competitors have been other governments, normal market mechanisms are absent, and we continue to muddle along. This does not mean that all of our problems would be solved if we merely turned space launch over to industry, and restricted the government's role to supervising the purchase of tonnage per year to orbit. The contrary fact is true; the government's role in sponsoring appropriate technology and systems development is crucial, if effective launch vehicle technologies and an efficient free market in space transportation are ever to exist. We simply need to do it better than we have so far demonstrated.

In the wake of the *Columbia* accident, some have argued for restricting, once again, the frequency and purposes of manned spaceflight, or of restricting shuttle launches to orbits compatible with the International Space Station (ISS). One hears it said that manned spaceflight should be restricted to those occasions when human presence is "needed." I cringe when I hear or read such views. Since there was no human spaceflight at all prior to 1961, it is plain to see that we do not "need" to do it. We do it from a fundamental desire, inherent in our genes and in our culture, to explore our environment and expand our presence within that environment. We do it, according to John F. Kennedy's ringing quote, "not because it is easy, but because it is hard." Bearing this in mind, I submit that NASA's role is not to figure out how to do less manned spaceflight; NASA's role is to figure out how to do more of it.

With these thoughts in mind, I offer the following in response to the questions posed by this committee in its formal invitation to appear.

- *What key factors should be considered when evaluating human space transportation architectures? Is the proposed ISTP an overly optimistic or overly conservative approach to meeting NASA's needs? What areas of the proposed approach pose the greatest risk? What recommendations do you have to reduce these risks?*

The key element of any system architecture is that it be responsive to an overarching framework of goals. When a system architecture—or a specific vehicle—is designed without reference to such top level goals, the result is a point design that is unlikely to blend smoothly into any larger picture. Rather than being designed to meet a higher purpose, the purpose becomes merely that set of tasks the system can accomplish.

The proposed ISTP seems to lack the required global framework, the desired broader view. Three elements are specified—the Space Shuttle, a new Orbital Space Plane, and a reusable launch vehicle. This latter element, potentially the most important of the three, is hardly a factor in the present discussion because it is being deferred for some unspecified period. What, then, are the questions being asked, for which these three architectural elements are the answers? This discussion is nowhere to be found in the proposed ISTP.

NASA should lead the debate to define and enunciate the Nation's goals in space, and following from them, our goals in the development of space transportation—

goals which will guide us for at least a generation. These goals should be embraced within the Administration, and shared and supported by the Congress, for in this matter there is no conceivable partisan interest. Properly chosen goals will be shared by the majority of informed stakeholders, and will be broad enough to accommodate the flexibility of timing and funding that future Administrations and Congresses will need and want, without sacrificing their essence.

While others may certainly have their own ideas as to the appropriate goals for the Nation in space transportation, I believe they should include *at least* the following:

— Robust and economical small, medium, large, and heavy lift capability to LEO, to the 100 metric ton level or greater.

— Dependable, available crew transport to and from LEO.

— Crew escape capability from ISS and other space stations yet to be built in other places.

— Reliable cargo transport to LEO, including the capability for automated rendezvous, proximity operations, and docking with pre-existing assets.

— The option, but *not* the requirement, to combine crew and cargo transport as needed for a particular mission.

— LEO-to-higher-orbit transfer capability.

— Efficient lunar and interplanetary transfer capability for both unmanned and manned missions.

If I may be permitted an imperfect but possibly useful analogy, NASA is the entity in the U.S. government charged with, and best suited to, creating the "interstate highway" to space. This highway needs to be designed to handle shipments both large and small, on known and reliable schedules, safely and economically. The highway is needed because the existing patchwork of separately developed roads is inadequate to serve the future we can envision. Industry can and must share in the design, and must perform the actual construction. But only NASA can enunciate the goals and architect the system.

Against this larger backdrop, the proposed ISTP can only be seen as far too conservative. It is not so much wrong, as it is incomplete. If fully realized, it would leave us with little more capability than we have today to go beyond Earth orbit. It would do nothing soon to reduce the cost of space access. It would saddle us for the next two decades with continued primary reliance on the Shuttle, which is by any reasoned measure the riskiest element in the system. Surely we can do better.

- *How might the OSP alter NASA's reliance on, and the flight rate of, the Space Shuttle? Should crew and cargo delivery be addressed by separate systems? If the OSP and a separate cargo delivery capability for logistics re-supply were developed, would it be necessary to continue to fly the Space Shuttle? If so, what missions could not be accomplished without the Space Shuttle? If the Shuttle is required for the duration of the Space Station, is an OSP that performs both crew rescue and crew transportation required?*

Given the existing Leve1 1 requirements and their interpretation, the OSP is unlikely to alter substantially NASA's reliance on the Space Shuttle.

The OSP program is specified solely in terms of its requirements to "support" the International Space Station (ISS), where "support" is defined as "supplementing" the existing capabilities of Shuttle and Soyuz. It must support ISS crew rotation on 4–6 month intervals, and system is to be designed to have minimum life cycle cost. These constraining assumptions, offered without reference to a set of higher goals such as articulated above, will have profound consequences in the generation to come. To see where these assumptions can lead, let us consider the following train of thought.

If the purpose of OSP is to "support" ISS operations by "supplementing" the capabilities of the Shuttle, and ignoring Soyuz for the moment, then clearly the Shuttle must be kept flying, in accordance with the proposed ISTP. Estimates vary, but it is accepted that a viable Shuttle program requires a minimum of several—let us say three or four—launches per year. Thus, in the normal course of events, Shuttle alone can easily accommodate ISS requirements. OSP would then fly only a couple of times per year—if that—to maintain operational currency, or to rotate the vehicle(s) docked at ISS for purposes of emergency crew return. Under these assumptions, OSP is thus needed only when—as at present—the Shuttle is grounded. The OSP system thus needs to be designed to accommodate a peak rate of possibly four flights per year for short periods, and much less on average.

With such assumptions, it will be almost guaranteed that the lowest-life cycle-cost design is a simple (probably expendable) vehicle with the least capability consistent with completing the tasks envisioned today. A basic semiballistic capsule designed for a few days of independent flight could easily suffice. By choosing this path—and it is inevitable if we accept the Level 1 OSP requirements as written—we accept the requirement to maintain the inherently high cost Shuttle program. Worse, we have as our only Earth-to-LEO transportation systems two designs (Shuttle and OSP) which are wholly incapable of being adapted to the needs of lunar return or Mars exploration, ventures which should certainly be of interest over the intended design life of the OSP. Considered in such a broader context, radically different design choices might be made for OSP. But they are not possible given the requirements as written.

It scarcely needs to be said that it will be extremely hard to justify the development of such a vehicle, at a cost of several billion dollars, for such a limited purpose as OSP will have, given the requirements envisioned for it today. And, indeed, such development makes little sense economically. One could likely obtain several replacement Shuttle orbiters in a "block buy" for the same cost as a new OSP. Further thought in this direction would likely show that the most economical crew return vehicle for ISS would be the Shuttle itself—modified for a 60-to-90 day stay—with four to six crew rotation missions per year. Following this logic, it becomes difficult to see the path by which reliance on the Shuttle can be ended.

To me, the likeliest result of accepting the OSP Level 1 requirements as written is that a sober analysis will show the OSP to be wholly unjustifiable in economic terms, and the program will subsequently be cancelled in favor of continued use of the Shuttle. Since the Shuttle is not capable of supporting the larger goals that I have enunciated above, or any similarly broad set of goals, I would consider this outcome to be another setback for NASA and the Nation.

With regard to separation of crew and cargo, the issue is not "should" they be separated, but "can" they be separated when it is advantageous to do so, as is so often the case. With the Shuttle, they cannot. While the Shuttle's large cargo bay is its most impressive feature, it is also the feature which, in my opinion, results in the greatest increment of risk to the astronauts who fly it. With the cargo bay attached to the crew cabin, the Shuttle orbiter is inherently so large that only a sidemount configuration is possible, leaving the crew with no escape path in the event of a launch malfunction, as with the *Challenger* failure, and vulnerable to falling debris, possibly including ice, as with the *Columbia* accident.

If the Shuttle system had been designed with a smaller manned vehicle atop an expendable cargo pod, the overall system would have been much safer. A simple escape rocket would have sufficed to separate the crew vehicle from the launch system in the event of a malfunction, which is of course ultimately inevitable, given a sufficient number of flights. The crew vehicle could have been launched, by itself, on a smaller vehicle or vehicles when no cargo was required. The only lost capability would have been the ability to handle "down cargo," the least used feature of the Shuttle system. My own view on the value of "down cargo" is somewhat simplistic: It is so difficult and expensive to get payloads to space that, having done it, we ought by and large to leave them there, and design them for that! But, if necessary, I believe that the design of a reusable cargo pod capable of executing an autonomous re-entry and landing would pose little challenge.

- *Given that the OSP program has not yet progressed beyond establishing the Level I requirements, do you think NASA's plan for spending approximately $750 million on technology demonstrations between FY03 and FY06 is justified? What technologies are the most critical to demonstrate before proceeding to full scale development?*

Numerous advances in thermal protection materials technology have been made since the Shuttle was designed and built, and some relatively inexpensive demonstrations may be useful in this area. Automated rendezvous and docking, a procedure so basically straightforward that the Russians first demonstrated it more than three decades ago, remains to be demonstrated in the U.S. program. Crew escape system technology has been essentially absent from U.S. vehicles since Apollo, and may need some investment. Isolated technology demonstrations may be required to address issues relevant to a particular vehicle design, once such a design is selected. However, these are details. I am unaware of any crucial, but as yet unproven, technology needed for Earth-to-LEO transportation. I believe money spent on technology demonstrations would, in general, be better spent on vehicle development. Such an approach would also offer the benefit of significantly shortening the planned OSP development schedule.

- *What design alternatives should NASA examine as it performs its concept studies for the OSP? What changes to the OSP program would you recommend to reduce the cost or accelerate the schedule? How does the decision to proceed with a design that is totally reusable, partially reusable, or expendable drive design complexity, development schedule, cost, and safety? Can the OSP schedule be accelerated significantly without introducing unwarranted risks? If so, what recommendations do you have?*

We should be careful to avoid overburdening OSP with ISS crew return vehicle (CRV) requirements. My view, harkening back to my involvement in the 1993 Space Station redesign effort, and before, has always been that the CRV is properly viewed as a "lifeboat," to be used in an emergency, and likely not otherwise. As an order of magnitude estimate, we might expect to use it once per decade. If it is used regularly or routinely, we are doing something seriously wrong with regard to the operation of ISS, something which needs to be remedied. But stretching the notion of what constitutes a CRV is not the answer. Therefore, again in my view, crew transport requirements should determine the OSP design, with CRV requirements at the margin.

As an aside, I have personally never been able to understand why a refurbished Apollo spacecraft cannot be outfitted as a perfectly acceptable CRV. The need for developing a new vehicle to meet the crew escape requirement has never been obvious to me.

Much in the news recently, and for good reason, is the question as to whether the "Orbital Space Plane" should be a "plane" at all. In the wake of the *Columbia* disaster, some have called for a return to a "capsule" design, more properly termed a "semiballistic entry vehicle." Certainly there is strong merit in such a recommendation. A semiballistic vehicle offers a number of advantages for Earth-to-LEO transport. It is likely to be more volumetrically efficient and to have less mass than a winged vehicle for the same overall mission requirements, and is much better adapted to any requirements to go beyond low Earth orbit. Either design can be equally reusable, with the possible exception of the heat shield for the semiballistic vehicle, which will almost surely encounter a higher heat load than for a gliding entry vehicle. However, and in strong contrast to a winged vehicle, the semiballistic can be designed such that the heat shield is both very simple, completely separable, and easily detachable from the core vehicle, resulting in a system with only one non-reusable component that is not particularly weight critical and can be, almost literally, dirt cheap.

It is often stated that the landing accuracy of a semiballistic vehicle will be inferior to that of a winged design. This is nonsensical. If a parachute or parasail is used, today's steerable designs, with pinpoint GPS guidance, allow either design to achieve highly accurate landing point control. Furthermore, historical data indicates that even without benefit of steerable parachutes and GPS, entirely acceptable landing accuracy can be obtained. The table below cites the mission-by-mission Apollo landing accuracy (from "Apollo Program Summary Report," NASA TM–X–68725, National Aeronautics and Space Administration, Johnson Space Center, Houston, TX, April 1975). It is seen that the worst case landing dispersion would have been trivially contained within the boundaries of Edwards AFB, or White Sands Missile Range, or even within acceptable landing areas at Cape Canaveral or Wallops Flight Facility. Most of the Apollo landing dispersions would have fitted easily within the boundaries of Dulles Airport. It is not necessary to do better than that.

Apollo Landing Accuracy

Mission	Distance from Target (mi.)[1]
Apollo 7	1.9
Apollo 8	1.4
Apollo 9	2.7
Apollo 10	1.3
Apollo 11	1.7
Apollo 12	2.0
Apollo 13	1.0
Apollo 14	0.6
Apollo 15	1.0
Apollo 16	3.0
Apollo 17	1.0

[1]Best estimate based upon recovery ship positioning accuracy, command module computer data, and trajectory reconstruction.

Note the phrase above, "if a parachute is used." It is not obvious that a parachute is necessary (other than possibly as a backup system, wherein the goal becomes crew, rather than vehicle, survival). The terminal velocity of a semiballistic vehicle will be on the order of 300 miles per hour, probably less. Braking rockets ignited at high altitude, initially at idle thrust, and then smoothly throttled to touchdown can serve quite well, as the DC–X and DC–X–A programs have shown. Besides demonstrating the ultimate in pinpoint landings in the nominal case, these efforts also showed how a backup parachute landing system can be efficiently incorporated into the design, and used effectively in an emergency. Detailed studies have continued to reveal no substantive mass difference between a semiballistic design with terminal rocket braking, and a more traditional winged design.

Of course, there is also the possibility of using conventional parachute descent, with surface contact cushioned by short duration, high-thrust rockets as in the Soyuz design. Thus, there is no need to assume the inconvenience of an Apollo-style water landing if a semiballistic design is chosen, except possibly in a dire emergency when, in contrast to a winged vehicle, the ability of a semiballistic to survive a ditching then becomes an attractive option.

However, because we should carefully consider the merits of a semiballistic crew vehicle design does not mean that we should ignore the merits of a winged design. Various lifting body research programs, as well 198 successful X–15 flights and 116 successful Shuttle landings (including approach and landing tests with the Enterprise vehicle) have demonstrated the efficacy with which unpowered descent and landing can be performed. Highly efficient blended delta-wing, lifting body shapes, such as the NASA Langley HL–20 and its derivatives, have been thoroughly characterized. So there is a wide range of attractive options available.

When considering winged vehicle designs, however, I think we have ignored one of the best options, the straight-winged design, for somewhat specious reasons. All else being equal, it is well understood that a straight-wing design will have less mass, lower heat loads, a higher subsonic lift/drag ratio, a lower landing speed, a shallower glide path on approach, and better subsonic handling characteristics than a comparable delta-wing design. The delta-wing design offers as its principal advantage a somewhat greater entry crossrange capability than for a comparable straight-wing design. This allows greater maneuverability from orbit to reach a given landing site, as opposed to waiting on-orbit for perhaps half a day for another opportunity to reach the site. The delta-wing design also allows the so-called "abort once around," meaning that the Shuttle can land at its launch site after only one orbit, in the event of a severe anomaly. This greater atmospheric maneuverability was the reason for its selection for the Space Shuttle design, and was a source of considerable controversy at the time. But in over a hundred Shuttle flights, operational practice has shown that this enhanced crossrange capability is at most a minor convenience, rather than a significant enabling feature. Any consideration of a new, winged, spaceplane should take these facts into account in determining a design configuration.

When contemplating designs for a new winged space plane, it may not be beyond the bounds of reason to examine the swing-wing concept, so successful on the F–14 fighter aircraft. Providing robust, mass-efficient thermal protection of the wing leading edges is among the most difficult, and unforgiving, tasks in a spaceplane design. With a swing-wing concept, it might be possible to avoid this task altogether. For such a vehicle, the atmospheric entry phase would be performed as a semiballistic design, while terminal area energy management, approach, and landing would be performed as a conventional winged vehicle. As always, there are tradeoff analyses to be conducted, but the concept may be worth pursuing.

The issue of OSP reusability is complex, which of course is why it attracts so much debate. The primary reason to prefer a reusable vehicle is that, in all reason, it should be cheaper to operate. Secondary reasons may include the fact that ground and flight crews gain experience with the nuances of a particular machine, a valuable benefit when compared to the obvious risks of undertaking a maiden voyage for every flight of an expendable vehicle. However, for the moment let us restrict the discussion to economic issues.

The economic benefits of reusability are strongly conditioned by the cost of incorporating the necessary features into the design and fabrication of the vehicle, and by its assumed flight rate and operational lifetime. As a simple example, if it will cost five times more to build a reusable vehicle than to build a comparable expendable design, the reusable vehicle must fly five times to break even with the expendable, assuming their processing costs are similar. Moreover, most of the cost for the reusable vehicle is incurred "up front," while a greater proportion of the expendable vehicle cost is incurred only when the next unit is actually procured. Time-value-of-money considerations can thus strongly benefit the expendable vehicle when flight rates are low, and when decisions are made on a lowest life cycle cost basis.

The issue of designing to minimize life cycle cost is worth some discussion. It should be noted that, over more than two decades of Shuttle operation, the program has encountered much criticism because year-to-year operational costs have been quite high when considered on a per flight basis. This has been directly traced, in part, to early 1970s budget constraints on initial design and development, when numerous choices were made which had the effect of minimizing (or appearing to minimize) development cost, while increasing operational costs. Again because of time-value-of-money considerations, the strategy of designing the vehicle to minimize development cost is closely akin to that of a design based on minimizing life cycle cost, especially when the vehicle will be in service for a long time. While neither principle is inherently wrong, each should be applied in moderation. Life cycle costs are heavily biased by early year, or "up front," costs. It is always easy to defer operational funding problems to the "out years." Yet, when the "out years" arrive, as they always do, we seem consistently to regret the pattern of earlier choices, which were of course intended to "save" money. Is it possible, this time, that we could at least make a new mistake?

As outlined earlier, it will be tempting on economic grounds to consider an expendable design for OSP, for the reasons just mentioned. I believe this is a mistake; if done, it will represent a failure of government to lead where industry, by itself, cannot go. An argument to go backward, toward deliberate use of expendable vehicles for manned spaceflight, is an argument which inevitably favors the doing of less manned spaceflight, precisely because out-year operational costs will always been seen as unacceptably high when the out-years arrive. This should not be our goal.

With respect to cost, I would like to offer a cursory figure of merit, a target cost-per-pound of delivered hardware. It is well established within the aerospace community that such figures of merit offer a valid first-order estimate of likely program cost; indeed, such parameters form the basis of all accepted cost models. Therefore, I would advocate that the OSP design, development, test, and evaluation (DDT&E) costs should be *upper bounded* at $100,000 per pound for the dry mass of the vehicle. The Nation's experience base with reusable manned space vehicles is limited, but both X–15 and the Space Shuttle orbiter would seem to fit this definition. In recent-year dollars, both were completed at a DDT&E cost of approximately $90,000 per pound of delivered hardware. If the OSP is allowed to cost more, we are conveying the message that nothing at all has been learned in 40+ years of manned spaceflight.

Regarding the program schedule, it seems inconceivable to me that a nation which required only eight years to reach the moon, from virtually a standing start, can require a similar or greater length of time to design and deploy a simple crew transport vehicle. If the OSP program requires more than five years—at the outside—from authorization to proceed until first flight, it is being done wrong. My primary recommendation, the only one I think can affect the outcome in a significant manner, is this: Define carefully the goals the OSP is to meet. Pick a strong, effective, proven, and trusted program manager, and accord to him or her the total authority and responsibility for success. Set aside the necessary funds, with adequate margin. And then see to it that everyone else stays out of the way.

- *What challenges may NASA face in using an Expendable Launch Vehicle (ELV) as the boost vehicle for the OSP? Does the use of an ELV for human spaceflight pose an unacceptable risk?*

In the 1950s and 1960s, the term "man rating" was coined to describe the process of converting the military Redstone, Atlas, and Titan II vehicles to the requirements of manned spaceflight. This involved a number of factors such as pogo suppression, structural stiffening, and other details not particularly germane to today's expendable vehicles. The concept of "man rating" in this sense is, I believe, no longer very relevant.

If a winged design is chosen for OSP, there will be an issue of coupling between the OSP vehicle aerodynamics and the launch vehicle structural dynamics. Briefly, the OSP must be oriented and flown very close to its zero-lift aerodynamic angle of attack. Any significant amount of lift on the OSP wings will create lateral loads at the OSP/launch vehicle interface that are quite likely unacceptable, at least without additional structural reinforcement at that interface. However, it must be said that launch vehicle loads are likely not the limiting factor; the wings of a spaceplane cannot themselves accept high lateral loads without being ripped off. The problem is a familiar one; the Shuttle must be flown with a nearly zero angle of attack for similar reasons.

Therefore, irrespective of the launch system used for a winged OSP, the vehicle must be flown at essentially a zero-lift angle of attack, and any variations due to vehicle aeroelasticity must be carefully controlled. While the problem is certainly not trivial, it is not likely to be any more difficult for the new evolved expendable launch vehicle (EELV) than it will be for a winged OSP attached to a future RLV.

The base reliability of unmanned expendable vehicles seems to arouse concerns where that of the manned Shuttle system inexplicably does not. Many, if not most, unmanned payloads are of very high value, both for the importance of their mission, as well as in simple economic terms. The relevant question may be posed quite simplistically: What, precisely, are the precautions that we would take to safeguard a human crew that we would deliberately omit when launching, say, a billion dollar Mars Exploration Rover (MER) mission? The answer is, of course, "none." While we appropriately value human life very highly, the investment we make in most unmanned missions is quite sufficient to capture our full attention.

Logically, therefore, launch system reliability is treated by all parties as a priority of the highest order, irrespective of the nature of the payload, manned or unmanned. While there is no EELV flight experience as yet, these modern versions of the Atlas and Delta should be as inherently reliable as their predecessors. Their specified design reliability is 98 percent, a value typical of that demonstrated by the best expendable vehicles. If this is achieved, and I believe that it will be, and given a separate escape system with an assumed reliability of even 90 percent, the fatal accident rate would be 1 in 500 launches, substantially better than for the Shuttle. Thus, I believe that launching OSP on an expendable vehicle would pose no greater risk—and quite likely somewhat less risk—for human spaceflight than is already accepted for the Shuttle.

BIOGRAPHY FOR MICHAEL D. GRIFFIN

Michael D. Griffin is President and Chief Operating Officer of In-Q-Tel, the independent, nonprofit venture group chartered to identify and invest in cutting edge commercial technologies for intelligence community applications.

Mike was previously CEO of the Magellan Systems Division of Orbital Sciences Corporation, and also served as General Manager of Orbital's Space Systems Group and as the company's Executive Vice President/Chief Technical Officer. Prior to joining Orbital, he was Senior Vice President for Program Development at Space Industries International, and General Manager of the Space Industries Division in Houston.

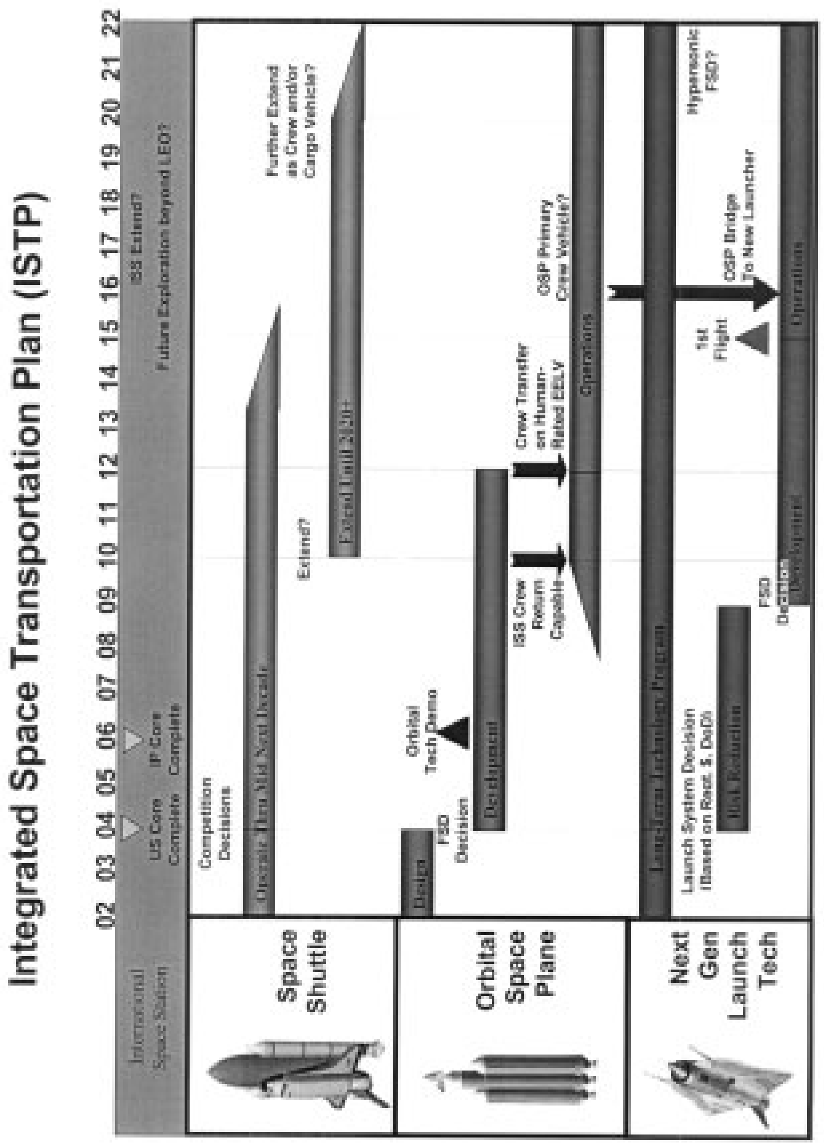
Mike has served as both the Chief Engineer and the Associate Administrator for Exploration at NASA, and as the Deputy for Technology of the Strategic Defense Initiative Organization. Before joining SDIO, he played a leading role in numerous space missions while employed at the Johns Hopkins Applied Physics Laboratory, the Jet Propulsion Laboratory, and Computer Sciences Corporation.

Mike holds seven degrees in the fields of Physics, Electrical Engineering, Aerospace Engineering, Civil Engineering, and Business Administration, and has been an Adjunct Professor at the George Washington University, the Johns Hopkins University, and the University of Maryland. He is the lead author of over two dozen technical papers and the textbook Space Vehicle Design. He is a recipient of the NASA Exceptional Achievement Medal, the AIAA Space Systems Medal, and the

DoD Distinguished Public Service Medal, and is a Fellow of the AIAA and the AAS. He is also a Registered Professional Engineer in Maryland and California, and a Certified Flight Instructor with instrument and multiengine ratings.

DISCUSSION

Chairman ROHRABACHER. Thank you very much, Dr. Griffin. I guess I will start the questioning, and I wonder if we could have this graphic back up on the board up there, Mr. Gregory's graphic, is that possible? There it is.



Mr. Gregory, if you could—you know, I am taking a look at your graphic here of the Orbital Space Plane, and the big tanks here and can you describe for us what is on top of that tank there?

Mr. GREGORY. Well, that looks like a winged vehicle, but it was not intended to focus you in on something that looked like a winged vehicle. So I apologize for that and the lateness of the testimony.

Chairman ROHRABACHER. Oh, I see. So that really—what do we have in mind? If we don't have in mind a winged vehicle, could—maybe you could describe what is—we are going to put up there and what you have in mind now.

Mr. GREGORY. In this particular configuration, if you can disregard the tail on it, which you are looking at, what you would have is an unshrouded vehicle that could be either a Crew Transport Vehicle or a Crew Rescue Vehicle. In the Crew Transport Vehicle, and let me tell you why it is unshrouded. Part of the ability to increase the safety would be the ability to safely remove the crew from a launch vehicle. And so it would have to be unshrouded, and as such, it could not be in the Space Shuttle. And so at least on the Crew Transport Vehicle version of it——

Chairman ROHRABACHER. That—it would—what would it look like? I know it is not shrouded. Do you have a design for the——

Mr. GREGORY. No, sir, we do not.

Chairman ROHRABACHER. I think that is what I was getting at.

Mr. GREGORY. Oh, yes, sir.

Chairman ROHRABACHER. So in reality, we have this graphic, but we don't have anything at the end of these rockets, do we?

Mr. GREGORY. During the——

Chairman ROHRABACHER. So really there is nothing to put on the end of this graphic. It was just sort of thrown here. I don't—anyway, let me just suggest that my—if my memory serves me correctly, for the last five years, I have been personally supporting the allocation of resources that would—and to the tune of tens of millions of dollars both for Air Force and for NASA expenditures that would, in some way, develop an Orbital Space Plane, military space plane, you name it, Crew Return Vehicle, all of these. And we still don't have anything after spending all of those tens of millions of dollars that I personally have been involved in as Chairman of this subcommittee. We have got nothing to show for it up here. There is nothing to put on the end of your graphic. Let me just say I am disappointed, and we will leave it at that.

CANCELLATION OF ALT ACCESS TO STATION

I have another question. The size of the crew on the Space Station was just reduced from three to two. Is this a—is there a vote? Okay. The size of the crew on the Space Station was just reduced from three people to two last week, because we can not keep them supplied, as I noted in my opening statement, with water, food, and other supplies. Scientific research will thus be slashed from 20 hours to 9 hours per week, which was as you know, a reduction to a reduction. NASA's Alternative Access Program, which is intended to demonstrate the capability for just providing the various type of need that we are talking about, I guess that has been—now we are looking forward to ending that program. Now given that, how could we cancel that program that is designed specifically to deal with this challenge? And then—and with any straight face saying, oh, we are going to just rely on the Shuttle, which we all—which we know now is, you know, a risky proposition at best at this point. And if—and will this decision to cancel this program be revisited?

Mr. GREGORY. Certainly the *Columbia* accident has caused an awful lot of rethinking. During the reassessment, and certainly including the recommendations of the Adm. Gehman Board, we are looking at, certainly, what would have to be modified with the Space Shuttle, what the impact on the Space Station would be, perhaps new re-balancing with the international partners, but also we will look at the kinds of technologies that would be necessary in the future to support the future.

Chairman ROHRABACHER. But we have determined that the Alternate Access Program, which is aimed right at an immediate need, should be canceled. We are going to look at all of that other stuff, but here we have an immediate need at making sure that we get that supply to the Station, and that program is canceled, and we are not looking to that.

Mr. GREGORY. That program has been canceled, yes, sir. You are absolutely right.

Chairman ROHRABACHER. Does that make sense to you? It makes no sense to me.

Mr. GREGORY. Well, if you look back at how we got to this—as we got to this decision, we have to look back at how NASA was going to acquire the alternate access or the heavy-lift launch vehicles. It included quite an acknowledgment of a very large commercial market. That commercial market has decreased significantly. We are looking at common technology with the military at this point and that is ongoing. We are certainly now looking at what would be necessary as an alternate cargo transport capability, both up and down, and how that could——

Chairman ROHRABACHER. But you are looking at that within the context of just one particular program, not in terms of competition among various alternatives.

Mr. GREGORY. Well, we are looking at this not only for the near-term, but also for future terms as NASA expands its role.

Chairman ROHRABACHER. But you are looking at this within—just in the context of one program being evaluated in time rather than a program designed to look at all alternatives.

Mr. GREGORY. Sir, this summer, we will be looking at the entire spectrum, not just one alternative.

Chairman ROHRABACHER. But then why isn't it part of a—why isn't it organized into an organized decision-making rather than talking about the various projects that you are talking—in other words we have an access program that is now being canceled, right? It is this Alternative Access——

Mr. GREGORY. The Alternative Access Program has been canceled.

Chairman ROHRABACHER. Right. So but now you are telling me we are continuing to look at the various options individually.

Mr. GREGORY. We are looking at the kinds of technology that will be necessary to support whatever the future missions happen to be.

Chairman ROHRABACHER. All right. Well, anyway, we will—there will be a second round, but I do not want to hog my time here. Mr.

Gordon has some very important questions to ask as well. Mr. Gordon, you may proceed.

NASA WORKFORCE ISSUES

Mr. GORDON. Thank you, Mr. Chairman. Mr. Gregory, you digressed from your remarks to compliment Chairman Boehlert on his NASA Flexibility Act, so let me just quickly also digress. If Admiral Gehman were to say that his report would address some of the workforce issues that could be relevant within the NASA Flexibility Act, do you think it would prudent for us to wait to hear what he had to say a few weeks before that we pass this bill?

Mr. GREGORY. Well, I think that the—I think the bill includes more than just the workforce as associated with the Space Shuttle.

Mr. GORDON. Right, but I mean but if Admiral came and were to say that his report could have information relative to this bill, do you think it would be prudent for us to wait a few weeks and hear that?

Mr. GREGORY. At this point, Mr. Gordon, I have not heard any feedback from Admiral——

Mr. GORDON. Well, let us just—again, if Admiral Gehman—let me—this is—I think this is a fairly clear question, isn't it? If Admiral Gehman were to say that his Board could have some recommendations concerning the workforce that would be relevant to this bill, do you think it would be prudent to wait to hear from him before we pass this bill?

Mr. GREGORY. No, sir, I don't believe so. I believe that the content of the bill should cover—if Admiral Gehman should recommend changes, they should cover all of the problems.

Mr. GORDON. Mr. Gregory, I would say that is a sloppy way to approach legislating, and I hope that you will take a little more seriously your job and trying to listen to his recommendations on fixing the Shuttle.

Mr. GREGORY. Sir, you are presupposing Admiral Gehman.

Mr. GORDON. No, sir, I am—well, let me just tell you this. Admiral Gehman told us, told the Chairman, told me, told Chairman Boehlert that their report would have recommendations concerning the workforce.

Mr. GREGORY. Well, this——

Mr. GORDON. So let us put it in the specific, so now that he said that it will, do you think it would be prudent for us to listen to what he had to say before we pass this legislation?

Mr. GREGORY. Sir, I believe that the content of the legislation would not be effected one way or the other by Admiral Gehman's——

Mr. GORDON. Well, how are we going to know? You said, you know—how are we going to know that until we hear what Admiral Gehman has to say?

Mr. GREGORY. Well, you have heard, sir, and I——

Mr. GORDON. I know, and he stated he would.

Mr. GREGORY. Well, have you looked at the bill? Can you determine if there is an impact?

Mr. GORDON. I—all—I haven't heard—Admiral Gehman has only told us that he will have recommendations concerning this. He has not told us what they are, and that is why, again, it would seem to me prudent legislating would mean that we should listen to what he has to say before we—knowing he is going to come before us just in a matter of weeks. Again, I think it would be sloppy otherwise. You can take what—however you are going to do your job the way you think you need to do it.

CANCELLATION OF X–38/CRV

Let me move on. Mr. Gregory, I have a number of questions about the Orbital Space Plane that I would like to cover with you and other witnesses today, however, I want to take a minute to talk about something that has been very troubling. Last June, Mr. Hall, the Ranking Member of the Committee, wrote to Administrator O'Keefe about the cancellation of the X–38 program. In response to one of Mr. Hall's questions, Ambassador—or rather Administrator O'Keefe wrote, on September the 30th, the following response: "Based on an independent assessment of X–38 CRV project conducted in 1999, an X–38 CRV program would cost approximately $3 billion depending on the approach used in design, development tests and evaluation, and production." That didn't square with what we have been told previously, so Mr. Hall and I asked for a copy of that assessment. What turns out that the Administrator's characterization of the study was not accurate. What the aerospace study actually said was that CRV fleet costs would cost $2.45 billion if NASA followed a business-as-usual approach and that the CRV fleet would cost only $1.26 billion if NASA followed the approach advocated by the X–38 Project Officer. And your cost analysis division acknowledged as much in the summary charts that came over with the study. And Mr. Gregory, I am concerned that NASA would tell the Ranking Member of this committee something that appears to be both inaccurate and misleading, and we never would have found this out if we hadn't asked for the report. So Mr. Gregory, do you agree with me that NASA's response to Mr. Hall was misleading?

Mr. GREGORY. I think that NASA's response to Congressman Hall was accurate.

Mr. GORDON. Well, then let me—I don't want to take the time of the Committee, so if—would you write us and explain why you think——

Mr. GREGORY. I will.

Mr. GORDON [continuing]. It was not misleading since you——

Mr. GREGORY. Yes, sir, I will.

Mr. GORDON. Okay. Thank you. Okay. And the reason I raise this, we are—you know, we really want to try to do our job properly. We have to have good information and credible information. And we need to have a trusting relationship that we are getting that information. So if on the surface it seems pretty clear to me, but I would appreciate then you can write us and tell us why you disagree.

Mr. GREGORY. Thank you.

[The information referred to follows:]

National Aeronautics and
Space Administration
Headquarters
Washington, DC 20546-0001

Reply to Attn of: L:MDK

JUN 13 2003

The Honorable Bart Gordon
Ranking Democrat
Subcommittee on Space
and Aeronautics
Committee on Science
House of Representatives
Washington, DC 20515

Dear Mr. Gordon:

During the Subcommittee's hearing on May 8, 2003, concerning the Orbital Space Plane program, you requested that NASA provide written clarification of an Agency cost estimate of the X-38/CRV program. Specifically, you requested clarification of the following statement that was included in a letter from the Administrator to the Committee dated September 30, 2002:

> "Based on an independent assessment of the X-38/CRV project, conducted in 1999, an X-38/CRV program would cost approximately $3 billion, depending upon the approach used in design, development, test and evaluation, and production."

During the hearing, you noted that there appeared to be an inconsistency between the Administrator's statement and the "business as usual" estimate of $2.5 billion and a "rapid prototype estimate" of $1.3 billion" included in the 1999 independent assessment.

It is true that the figures included in the 1999 Independent Program Assessment Office (IPAO) report included the $2.5 billion and $1.3 billion estimates. However, the IPAO estimates assumed funding for the X-38/CRV in the years FY 1999-2005. At the time of the Administrator's letter to the Committee in late FY 2002, it was obvious that the funding estimates being provided should reflect "FY 2003 and outyear" dollars. When the $2.5 billion estimate for "business as usual" was converted to "FY 2003 and outyear" year dollars, the estimate was converted to $2.908 billion, which is consistent with the "approximately $3 billion" figure used in the Administrator's letter. The figure used in the letter focused on the higher end of the range (i.e. the $2.5 billion, which converts to $2.9 billion) because many observers of the X-38/CRV program had doubts that a "rapid prototype approach" was suitable for a human-rated vehicle that would be required to service the International Space Station, and that it would be prudent to use the more conservative cost number.

In summary, the IPAO report does quote $2.5 billion for a "business as usual approach" to X-38/CRV, but when this value is converted to the budget years that correspond to the Administrator's letter, the $2.5 billion estimate inflates to $2.9 billion (or rounded to $3 billion). Thus, your statements relative to the IPAO estimate are accurate, as are the estimates used in the

Administrator's letter of September 30, 2002, and referenced by the Deputy Administrator during the May 8, 2003, hearing—the estimates are simply using different "year dollars."

We would be pleased to discuss this matter further, if you wish.

Sincerely,

Charles T. Horner, III
Assistant Administrator
for Legislative Affairs

Mr. GORDON. Now, Mr. Gregory, I am—I need to move quickly here. I am trying to understand the rationale for the Orbital Space Plane, so I am going to ask you some quick questions here. It is my understanding that the Orbital Space Plane does not replace the Shuttle, the Space Shuttle but simply supplements. Is this correct?

Mr. GREGORY. When the Orbital Space Plane begins its operation, as far as the crew transport portion of it would, it would supplement.

Mr. GORDON. Right. So the answer to that is correct?

Mr. GREGORY. Yes.

Mr. GORDON. Okay. I am just trying to—I am not trying to hurry you, but I don't want to—I have a limited amount of time here. It is also my understanding that you plan to continue flying the Shuttle to the Space Station to deliver cargo and bring cargo back, is that correct?

Mr. GREGORY. That is correct.

Mr. GORDON. So under your current plan, you will be flying both the Orbital Space Plane and the Shuttle to the Station, is that correct?

Mr. GREGORY. That would be correct.

Mr. GORDON. So accelerating the Orbital Space Plane program, even if it were possible, wouldn't allow us to shut down the Shuttle program any sooner, is that correct?

Mr. GREGORY. Well, there is a decision point in the middle of the next decade where we would make that decision, sir.

Mr. GORDON. But still, that decision point is out further, so you still wouldn't be shutting down the Shuttle program any time soon?

Mr. GREGORY. No, sir. When we got an operational Crew Transport Vehicle and Crew Rescue Vehicle, there would be a period of time where there would be a transition. And then as the transition began to prove further, the reliability and the safety and the flexibility and——

Mr. GORDON. But you sure aren't going to have the flexibility to do cargo and other heavy loads.

Mr. GREGORY. The Shuttle, in fact, could be downloaded from a human transport, as——

Mr. GORDON. Okay.

Mr. GREGORY [continuing]. Was——

Mr. GORDON. Right. But you are still going to have to have them both. I assume you are going to take heavy cargo or——

Mr. GREGORY. Yes, sir.

Mr. GORDON. Okay. So that is—the answer is yes, specific to the question then.

Mr. GREGORY. Well, sir, let me qualify that. It certainly could be used as heavy cargo or whatever the next cargo vehicle happens to be.

Mr. GORDON. The Orbital Space Plane could be used?

Mr. GREGORY. No, sir. The Shuttle could be used.

Mr. GORDON. Right. Right. So you are going to have—I mean, simply put, you are going to have to have them both. You are going to have to have the Orbital Space Plane for your—for transporting your individuals. You are going to have to continue to have the Shuttle for heavy load.

Mr. GREGORY. Right.

Mr. GORDON. Okay. That is all I was trying to ask. So what do you estimate the marginal cost of the Orbital Space Plane flight to be?

Mr. GREGORY. I don't have that information, sir. I can provide that to you.

[The information referred to follows:]

MATERIAL REQUESTED FOR THE RECORD

Cost estimation for the Orbital Space Plane (OSP) is in progress. NASA is committed to providing responsible, credible cost and budget estimates prior to committing to new development programs. We will be following NASA policy guidelines of using the formulation phase of the OSP Program, to be completed by the end of FY 2004, to establish cost and schedule commitments for the implementation phase. At that point, the requirements and conceptual design will be sufficiently understood to ensure a responsible and credible development cost commitment is made. As part of the OSP system design process, each competing architecture contractor is providing life cycle cost estimates as a major deliverable. Government cost experts are developing cost estimates in parallel, utilizing legacy cost data from prior programs along with improved and validated cost analysis and estimating tools. A Cost Credibility External Review Team, reporting to the OSP Program Manager, is being established to provide expert assistance in ensuring credible cost estimation. In addition, an independent cost validation will be performed utilizing a Cost Analysis Requirements Document, as used by the Department of Defense and on the International Space Station Program. These various cost estimates will be studied and understood prior to the Full Scale Development decision. In addition, we are ensuring fiscal accountability on all ongoing OSP Program activities by using a proven Earned Value Management system to track actual cost and schedule performance as compared to plans.

Mr. GORDON. Okay. Thank you. Well, the working assumption on the OSP program is that you will need to launch it on a heavy EELV rocket, is that correct?

Mr. GREGORY. On an EELV or an ELV depending on which configuration you are talking about.

Mr. GORDON. All right. Now as I understand it, the price of a heavy EELV is in the range of $150 million per launch, and could wind up being much higher due to the lack of a big commercial market, is that correct?

Mr. GREGORY. Yes, sir.

Mr. GORDON. Okay. And then, of course, you have also got the cost of processing the Orbital Space Plane between flights, that is correct?

Mr. GREGORY. Yes, sir.

Mr. GORDON. Okay. So it seems reasonable to conclude that the Orbital Space Plane will cost as much and possibly much more than the Space Shuttle per flight, do you agree?

Mr. GREGORY. I can not answer that, sir. I don't know the answer to that.

Mr. GORDON. Well, do you know what the cost of the Space Shuttle is now? It is 115 million. So if the cost of the Space Shuttle is 115 million and you are going to have to be spending well over 150 million, then you are not saving any money, are you——

Mr. GREGORY. Well, I can't——

Mr. GORDON [continuing]. On the——

Mr. GREGORY. [continuing]. Discuss the relative costs, the marginal costs with you, but the—as we determine that there is an Orbital Space Plane requirement, we based it on improving safety, greater assured access to space, flexibility, and things of that nature. And so the discussion about the Orbital Space Plane, which is——

Mr. GORDON. [continuing]——but you are going to have to use them both.

Mr. GREGORY. It is not purely a discussion of money versus money.

Mr. GORDON. Okay.

Chairman ROHRABACHER. Okay. With that, we have a series of votes. Bart, let me note that I think $150 million guesstimate for the cost per Shuttle flight is fairly low. We had four flights last year, and I think it was a——

Mr. GORDON. That is the marginal cost.

Chairman ROHRABACHER. Marginal cost. For another one.

Mr. GORDON. Yes, because you have to keep it going anyway, so——

Chairman ROHRABACHER. I see.

Mr. GORDON. So the question of saving money then is off the table in terms of a reason to have the Orbital Space Plane.

Chairman ROHRABACHER. Now if you do have to take—if you do have to take the program going.

Mr. GORDON. Which he is—which he said that we do. So you—so there has to be other reasons, because you are certainly not saving any money there.

Mr. BARTON. Would the gentleman yield before we go for a break?

Chairman ROHRABACHER. I certainly will.

Mr. BARTON. I just want to add to what our Ranking Member and our Subcommittee Chairman said. It is an assumption that we are going to keep the orbital Shuttle going.

Chairman ROHRABACHER. Right.

Mr. BARTON. It is an assumption. I am very skeptical of that, and I hear a lot of skepticism by the Chairman and the Ranking Member on that. So that may be an assumption that is a false assumption.

Chairman ROHRABACHER. Right. Would—this is a very important hearing. We need to discuss this. We are the ones in Congress who are going to be most involved with making the decisions on these things once we hear from the Gehman Commission. I would suggest that we go for these four votes, we grab a quick bit to eat and be back here at 12:30. And we will resume this hearing at 12:30. Thank you very much. Until then, we are in recess.

[Recess.]

ENDING THE SHUTTLE PROGRAM

Mr. BARTON [presiding]. The Subcommittee will come to order. Chairman Rohrabacher is not yet back, and he has asked if I would reconvene the hearing. We had—when we recessed, Congressman, I think, Gordon had asked the last round of questions, so we are going to—I am the next one to ask questions, so the Chair would recognize himself for five minutes.

I would like to make a statement first. I was on this subcommittee back when the *Challenger* accident occurred. We had a debate at that time whether to build a new technology Orbiter. Congressman Nelson was the Subcommittee Chairman. He is now a Senator. He is one of the two Congressmen who have been in space. We decided because the Orbiter fleet was so young and we thought we could correct the problems that we didn't need to build a new technology Orbiter. We have now had the *Columbia* accident. I am a registered professional engineer. Our Chairman has returned as I say this, and an accident rate of one every 62½ missions and 14 Americans have lost their lives is not acceptable. And it is my opinion that we can't make the existing Orbiter as safe as it needs to be. The original programs, the Mercury program, the Apollo program, the Gemini program, basically had military astronauts who were, most of them, former test pilots. And we assumed that it was acceptable, the amount of risk to get the programs going. I don't think that it is acceptable now.

So my statement is, you know, I am not going to vote for any funding for the existing Orbiter to go back up into space. You know, I think we ought to scrap that program. I think we ought to spend the money on building the best technology Orbital Space Plane that we have. If it takes 10 years to do it, so be it. We put a man on the moon between 1961 and 1969 in the Apollo program. We certainly have the technology to do something similar today, if we were to decide we want to put the resources into it. Now that is the $64 question: is this country willing to put the kind of resources into manned space flight with the new technology Space Plane or Orbiter that we did in the Mercury and the Gemini and the Apollo days? And I don't know the answer to that. But I am just not going to sit by and put Americans at risk every time they go into space. If we had the same accident rate in our commercial aviation industry, thousands of people would be killed everyday in this country, and we would not accept it.

So the other questioners have been a little more elliptical, a little more nonjudgmental, but I don't want to go through another investigation if I am in Congress six or seven or eight years from now when we have the third Orbiter crash and kill another five or six or seven astronauts. I am just not going to do that. So I am going to ask you, Dr. Griffin, in your testimony you mentioned you were the—you came the closest to being skeptical about the existing Orbiter still being used. Do you want to elaborate on that?

Dr. GRIFFIN. Yes, sir. Thank you. I am not—I would not consider myself skeptical. I want to phase-out the Shuttle, no ifs, ands, or buts. I think that is the right thing to do. Given the investment we have in International Space Station today and given that it must be supported or eventually it will come down, and given that today there is no other means to support it, in the words I used in my testimony, we must do those things minimally necessary to fly it until we can replace it with a, I hope, better system.

Mr. BARTON. Well, how soon, in your opinion, and I am going to give Dr. Gregory—or Mr. Gregory an opportunity to answer this same question. How soon, in your opinion, could we come up with an alternative Space Plane or Orbiter that could service the Space Station if we just stop putting resources into the existing Orbiter fleet?

Dr. GRIFFIN. I think we need six months to study the issues and make the decision on which of several attractive paths we would like to go. And if we are not flying five years after that decision is made, we have done something wrong.

Mr. BARTON. Okay. Mr. Gregory, would you like to respond to that?

Mr. GREGORY. If you—your question, as I understand it, is if we stopped the Shuttle right now——

Mr. BARTON. Stopped putting all resources into it is——

Mr. GREGORY. But basically don't fly it again.

Mr. BARTON. Yes, sir.

Mr. GREGORY. Then I would guess that we would be talking about an activity that might be in line with Apollo, if you are only talking about human back and forth, not cargo. And I would guess——

Mr. BARTON. I am a proponent of manned space flight. I have got a record a mile long. I am not some—I don't want to anger my democratic friends, but I am not some wild-eyed, tree-hugging liberal who has been against the space program. I am as strong a proponent of it as there is, but I just—I don't think you can sustain the safety of the existing Orbiter fleet in a way that is acceptable.

Mr. GREGORY. You know, part of this Orbital Space Plane program that includes crew transport has taken into consideration your concerns. And if you were to do that without a requirement to support the Shuttle and if the Shuttle costs were not subtracted, then I would guess that in the 7- to 8-year period you could have a replacement for the human portion of it, not the cargo. So I think I am in line with Dr. Griffin.

Mr. BARTON. Well, my time is expired, and I am going to turn the Chair back over to the Subcommittee Chairman, but I will vote for expanded resources for manned space flight. I will argue for it on the Floor. I will fight for it at the Appropriations Committee, with the Senate, and with the President, if necessary. So I am not backing away from that commitment, but I am through turning my eyes to an accident rate that costs human lives at the rate that the existing orbital fleet does. It just—it is not, to my mind, the right approach any more. I don't know where the rest of the Subcommittee and the Full Committee is, but that is where I am very firmly.

Chairman ROHRABACHER. We have this room until 1:30, and so we probably will utilize that time, and so everyone will get a second round, if they want it, and we will try to be as generous as we can. Let me note that there are alternatives overseas that can carry us through a few years while we develop things of our own. We will go probably explore that a little bit later on.

We have a very active Member, of course, from Texas, and—who has always got great ideas, but he is also very aggressive when it comes to these issues, so we are going to unleash him on you right now. Mr. Lampson.

Mr. LAMPSON. Thank you, Mr. Chairman. I love your introductions. Typically I look—try to look to the future. And I don't mean to turn to the back and to consider a decision that has been made, but I think it is important for us to recognize that when a decision is not made with the greatest of thought, that perhaps we can learn from it and hopefully do something different. And so in that line, I would—have a—some questions about just some things that I think are hard for us to be considering right now.

ISS CREW RETURN AGREEMENTS

Under the international agreements, Mr. Gregory, governing the International Space Station, the United States has a commitment to provide a crew rescue capability by 2006. We have already discussed all of that. And that the Russian commitment to provide the Soyuz return vehicle for non-Russian crew members expires in 2006. When the Administration canceled the existing CRV program in early 2001, what was the alternative while fulfilling that obligation through 2006?

Mr. GREGORY. Well, first of all——

Mr. LAMPSON. Or after 2006.

Mr. GREGORY [continuing]. After 2006.

Mr. LAMPSON. Yeah.

Mr. GREGORY. The Russians have always been committed to transport and return three folks. And during the time frame when we have three people on board, a combination of Russians and Americans, the Russian Soyuz was available for that. Even after 2006, the Russians are still available—are still responsible for transporting up and back three. Now at that point, as originally planned, the Station would be enhanced with a greater number than three, a number that was based on a set of science requirements. And so there will always be a Russian Soyuz in support of the Russian members on board.

The CRV, as you correctly identified, preceded by the prototype X–38, the CRV was supposed to be available in that time frame. In my searching of the documents and looking at the history, it appeared as though the X–38, when the CRV was scrubbed, was not going to be available as a prototype until the 2008 time frame. And the costs——

Mr. LAMPSON. Why did you—why do you—why are you saying that?

Mr. GREGORY. Well, the assessments that I have seen, sir, and I have reviewed as many documents, and we can provide all of those for the record, if you like, it talked about the 2006 or whatever the time frame was a bit optimistic in that it was probably going to be pushed to the right. At the same time, there were discussions about the cost. And I have seen, as you have seen the $1.3 billion, which was a rapid prototype of the—a number that was around $1.5 or $2 billion, which was business as usual, which is not a full cost, but the way we had previously accounted for things. But I have also seen numbers that were in the $3 billion to $5 billion.

And so I think that when they began looking at the X–38, exactly what its capability was, the indefinite availability and the imprecise cost, a decision was made to not use that as a vehicle, but to begin to look at a multi-purpose vehicle or a series of vehicles. And that is what my research has shown. And if it is any different from yours, perhaps we can——

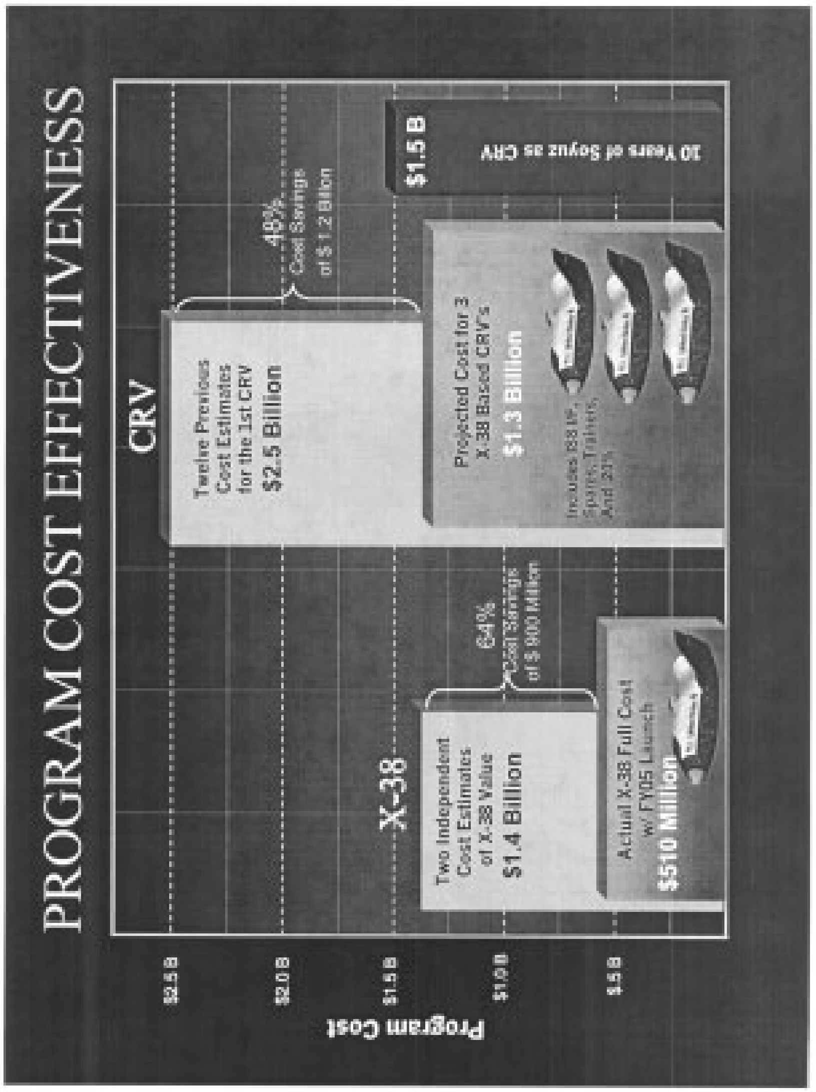
RESTART X–38/CRV

Mr. LAMPSON. I would appreciate it if you would provide that information for the record. And if I could ask our technician to put this chart up, please.

[The information referred to follows:]

MATERIAL REQUESTED FOR THE RECORD

NASA provided the cost assessment and documentation supporting the cancellation of the X–38 CRV project to House Space and Aeronautics Committee staff with formal notification to Congressmen Hall and Gordon by letter dated January 15, 2003. A copy of the letters and supporting documentation is located in Appendix 2: Additional Material for the Record.



This—I got this a year ago from the Team, the X–38 Team at the Johnson Space Center. And there was never—I never heard of any disagreement with the numbers that were put there. So I would be most interested in having the documentation of what you are explaining to us for the record for this committee. I think it is important for us to understand that.

The Orbital Space Plane wouldn't be available for crew returns. Well, no, let me back up for a second. We know that the language in your testimony, I think, said that when we go out for the bids or the design information on the Orbital Space Plane, we could reconsider use of a separate facility for a crew return, right. And that could certainly be, so can you tell me what it would take to restart X–38?

Mr. GREGORY. I think one of the strengths of the approach that NASA has now in both the acquisition strategy and also bringing on board the three primary contractors, I think in their deliberation, the X–38 could show up again as—or a derivative of the X–38. But it also might show an advanced capsule or something else. And so I think that I would not rule out something that looks like the X–38, but I have been waiting until these three primary contractors come back with their recommendations.

Mr. LAMPSON. It is—and I know that because we shut it down and in my opinion shut it down prematurely at a cost that would have been greater to complete at least the phase within which it was in that now that we give consideration to starting it back up that we will have made a decision that is going to cost us tens of millions of dollars if not hundreds of millions of dollars if we assume that that was a good decision.

Mr. GREGORY. Well, I don't know if we have agreed that we will start it up.

Mr. LAMPSON. I understand. I said if we chose to do that. I—there may be other things. But it seems to me that somehow or other we have—we don't always—haven't always looked at the best way to attack the problems that we are facing. And if we have a vision of something, if we know where we are going to go and it goes back to the comments that you all were saying a while ago or somebody, maybe it was Dr. Griffin, that if we are going to build a facility and another line of questioning that I didn't get to, and I am running out of time already, when we know that the Space Station is going to be phased out by 2016, at least considered to phase-out, we have no plan for the Orbital Space Plane beyond that. We are going to potentially use it for four years. We have an extreme cost for it. I really wonder the logic in what we are doing with the money that we have and what we are going to be doing beyond all of those times. And I will give back my time. We will come back to it in a few minutes.

Chairman ROHRABACHER. We will try to give everybody a second round. And we would now like to hear from Sheila Jackson Lee I believe was first. Go right ahead.

Ms. JACKSON LEE. Thank you very much, Mr. Chairman. And this is a very important hearing. Mr. Chairman, let me ask if I might put my entire opening statement in the record and ask unanimous consent.

Chairman ROHRABACHER. Oh, sure, without objection.

Ms. JACKSON LEE. And proceed. First of all, let me indicate to the panelists that we spent a lot of time reviewing your testimony, but the best part is being able to hear you. And I apologize. I was in Judiciary Committee with a hearing with respect to a large merger of a communications company, one owned by Ruppert Murddock, and so I was not able to be here at the beginning. But this is a very interesting area for me, and I would like to specifically offer my special welcome to Deputy Administrator Frederick Gregory. You were confirmed last August, and I hope and look forward to us having a series of meetings. Certainly I am very much impressed by your vast experience as an astronaut, and particularly your service on the safety and mission assurance issues that are going to be a great asset during these very tough times.

And I might add that we all suffer our ups and downs. Sometimes staff gets our materials in, sometimes they don't. So we are fully understanding of that, and I look forward to having the opportunity to chat with you on a number of issues.

Let me compliment as well the witnesses as it relates to the technology of the Orbiter plane. And my commentary and questions will not be in disregard of the importance of that technology. But I think it is important to highlight that the importance of a vehicle going to space and particularly the International Space Station is to carry crew, one, and to be able to carry cargo. That is very, very important, one of the enhanced tragedies. The first, and number one, tragedy, of course, of *Columbia 7* just recently is the enormous loss of life, the talent, the wonderful people that we lost, our family members from the Texas area. But added to that, of course, was the research that was lost. And so we understand the Orbital Space Plane, for example, will not be ready until four years before we shut down the International Space Station. And then we wonder, of course, why we are going forward with a design of a vehicle and we have not yet addressed the question of how many people we want to take into space.

So I am going to pose some questions on the safety aspect. As I say that, let me make it perfectly clear that I join Congressman Barton, my colleague from Texas. And of course, as I heard his words as I was entering the room, I am truly supportive, and I appreciate his support, because he is sort of way up the way in Texas on the manned space flight. But I join him, and I link with him. And I assume the Chairman, I don't want to speak for the Chairman, and certainly my colleague Nick Lampson, on the questions of safety. And certainly *Columbia 7* raises just nightmares. And I am hoping that this committee, Mr. Chairman, will soon be in the investigatory mode of reviewing and not just leaving it to the Committee that is there in Houston. They are doing a fine job, but they need to be before us on this investigation. I hope we will see that soon.

And the Soyuz, I am grateful to them that they landed, but they scared us to death. And I—that is something that I think is going to not be a standard of tolerance that we like to do so. OSP, what does the statement mean that the OSP will have a requirement to be safer than the Shuttle? And what does that mean, or the Russian Soyuz, what is the current level of catastrophic accident risk for the Shuttle? And what is the current level of catastrophic accident risk for the Soyuz? And if you can't provide these numbers, isn't it true that you can't define what it would mean for the OSP to be safer than the Shuttle or the Soyuz? And I would appreciate your response on those.

[The information referred to follows:]

MATERIAL REQUESTED FOR THE RECORD

The predicted risk of catastrophic Shuttle failure during a mission is 1 in 265. This risk was based on the 2000 update to the 1998 Quantitative Risk Assessment System (QRAS) model. The Shuttle program is completing a new probabilistic risk analysis for the Space Shuttle due out in the fall of this year.

The Soyuz refers to the launch vehicle and to the crewed spacecraft. Since 1980, when the current version of the Soyuz launch vehicle was put into service, it has flown 577 times, with 562 successful missions. The Soyuz spacecraft first launched on April 23, 1967; there have been two catastrophic failures out of approximately 89 missions.

I—and for a moment, Mr. Chairman, are you sitting in the chair over there? May I, just for a moment, just say that I would like those inquiries with respect to when we are going to get into the meat and flesh of the investigation of *Columbia 7* and I add to it Soyuz. I know your leadership, but I really believe that Congress has an obligation and duty to get into this in a very directed manner, but as quickly as we possibly can. There are many who are looking for questions, and they really do look, Mr. Chairman, from those answers, questions and answers, from the United States Congress. I——

Chairman ROHRABACHER. And with any luck, we will have a second round of questions for you today, so we should get on with the question and answers.

Ms. JACKSON LEE. Thank you, Mr. Chairman. The question——

Chairman ROHRABACHER. You may answer the question that was posed.

Mr. GREGORY. The requirement in the Level 1 says that it will be safer than the Shuttle and the Soyuz. We can look at the history of the Soyuz to determine what the number is. And if you allow me, I will provide that for the record. For the American Shuttle, based on probabilistic risk assessments and assessments that have been done prior to the *Columbia* accident, the entire mission was given a number like 1 in 250 or so, and please forgive me on the tens. For the ascent, it was 1 in about 500 or so. So in fact, the entire mission had a lower—or had a higher risk than just the ascent portion of it. And if that is okay, ma'am, I will provide the Soyuz numbers to you.

And so we are talking about something that is better than that. And when we talk about a vehicle of some sort on top of an expendable launch vehicle, and my apologies to the Chairman, I can't define exactly what it looks like, but with the escape mechanism, it is anticipated that our safety would be greater for the crew with that configuration.

Ms. JACKSON LEE. Thank you. I would like to pursue it, if I have the opportunity to be here for a second round and to press the envelope on this issue. Thank you very much, Mr. Chairman.

Chairman ROHRABACHER. And thank you very much. Is Mr. Sherman—has he left? Okay. We will make sure we go directly to him when he comes back, but in the meantime, we will start a second round of questions. And let me just note the frustration of this committee and it is—this is extraordinarily frustrating. And I mentioned earlier on that this—that I have personally been involved, as Chairman of this subcommittee, in making sure that revenues were available both through the Air Force and NASA for various projects that could be labeled military space plane or orbital maneuvering vehicle or whatever is up there. So you know, we—a Crew Return Vehicle, you name it, there has been money available for the last five or six years on this. I know. I helped put it in the budget. And yet we don't have any idea of what the configuration will look like much less have a blueprint ready to go. And here we are in the middle of a crisis. This does not speak well of America's space program and the people who are managing America's space program. And I am sorry. It is—maybe Mr. Myers, who was part of America's space program when it was being a little more successful, might want to comment on this overall problem.

Mr. Myers.

Mr. MYERS. Thank you, Mr. Chairman. I went through the Apollo program, and, of course, had one major accident in that program where we lost three brave astronauts. And I have always given them credit for a large part of the success of the Apollo program, because that accident galvanized every man in the program to do the very best they could possibly do in making a reliable spacecraft. And we proved it with Apollo 7 where it was judged to be 101 percent successful. And we proved it by going around the moon with a second Apollo manned flight. And we proved it with Apollo 11. We started the Shuttle program, because we saw there an opportunity to have a major breakthrough in cost of transport to space.

Well, it didn't turn out that way. We thought we could develop equipment as reliable as aircraft equipment. And it turned out that we still had to do the tender loving care of every part of the vehicle to make a successful flight. And that is where it has been ever since. It never has really matured to what a commercial aircraft——

Chairman ROHRABACHER. Is this due to management or is this due to just the fact that humankind has not reached a technological stage?

Mr. MYERS. I think it is the latter. I think that I have come to judge that the space programs, with the enormously difficult environment that we are involved in getting into space and the lack of immense production base of the components that are used for the spacecraft require that kind of individual attention to each of the components to be able to get a successful program. And I went through the—I watched the attempts on the part of NASA to make major improvements in the cost of launching to space. And you are all familiar with them. The single-stage-to-orbit was going to be the one—a giant step that didn't work. And the Tokyo Express with the supersonic combustion ramjet engines that didn't make it. And——

Chairman ROHRABACHER. X–33 didn't make it, you know, but——

Mr. MYERS. I give them credit for trying to make a major reduction in the cost.

Chairman ROHRABACHER. But you know, nobody gets—nobody ever gets credit for trying. It is what—it is people who do who get written in the history books. And it seems to me that we have been standing—you know, everybody says, "Oh, every generation, you know, has to stand on the shoulders of the last generation to reach even higher." It seems we are not standing on the shoulders of the last generation. It looks like we have been sitting in the lap of the last generation and not willing to—not reaching—in fact, we are not even reaching as high as the last generation. Mr. Griffin, what about it. Is it bad management of America's space effort that we haven't been succeeding and plowing any new ground or is it just that we have reached these technological impasses that humankind hasn't reached that level yet?

Dr. GRIFFIN. Probably will cost me the last friends I have in the world, but it is not the technology, it is the management. But it isn't just the NASA management. It is at the national level.

Chairman ROHRABACHER. Okay.

Dr. GRIFFIN. When we were doing Apollo, there was a consensus that we wanted to do Apollo. That didn't mean everyone agreed. I will remember that Senator Mondale attempted to use the unfortunate Apollo fire as a reason to cancel the program in—back in '67. But although it wasn't unanimous, there was a consensus that we were going to do it. That consensus led us to overcome the difficulties that are inevitably there, because we were operating at the technological state-of-the-art, as we are today, even though that state-of-the-art has changed. We can, if we wish, do more today than we could during Apollo, we just choose not to. So it isn't just NASA management, or for that matter, in DOD space management. It is at the national level.

Chairman ROHRABACHER. Well, you know, in every business operation, you know, you hear about the stories about not invented here as a syndrome for just not examining new ideas. And you hear about the various bureaucratic maladies that plague every enterprise. And I will say that I believe that these bureaucratic maladies are plaguing America's space program, and we have a situation where both in the political end as well as in the management end of America's space program. And by the way, I am not just talking about NASA here. I am talking about the big corporations that are involved in this as well. I don't see any courage on the part of major corporations at all in this area. And I will—what about you, Dr. Grey? The same—I am going to pose the same question to you and let everybody else get a chance to get in more detail on this, but I would like to—what is this? Is this mismanagement and incompetence or have we just reached this plateau where we can't do any more?

Dr. GREY. I am sort of halfway between Mr. Myers and Dr. Griffin. I think it is a combination of both. We have a very tough technological problem facing us. It has been facing us ever since we have started the program, ever since we began looking into space. Why did it take us 50 years to get into space in the first place? And the reason is because it is tough, and the technology is still tough and it is going to be tough.

Now as far as management is concerned, I think, to some degree, I have to agree with you that NASA has been wallowing in a kind of an indecision phase. The current indecision we are talking about is Orbital Space Plane, and yet the concept that I see is not just an Orbital Space Plane. It is kind of the beginning of the next reusable launch vehicle. We are mixing up the Orbital Space Plane and the NGLT. I think that is a mistake. I think the Orbital Space Plane has a near-term immediate concern, and that is servicing the Space Station, which has been pointed out as maybe another 10 or 15 years. But then we should accelerate the NGLT so that we can accelerate that decision to proceed to a true Shuttle replacement. And here I kind of support what Mr. Barton said. I don't want to see the Shuttle stop flying. I think it is still a good machine, if it gets fixed, but I think we do need a replacement for the Shuttle, and we have been stalling that decision for a long time.

So let us not confuse the Orbital Space Plane's mission and the Next-Generation Launch Technology, which is going to develop our next generation flying machine.

Chairman ROHRABACHER. Well, let me just go on the record before we open up to everyone, and I know there is to be a lot of questions in your direction to give you a chance to respond to this. But let me just say this for the record. We have got a lot of options here. And if anything makes sense, it is using your options to get by a crisis situation, and the Russians are providing us an alternative right now. Rather than trying to spend a great deal of our seed corn money and just getting through the crisis, we should make sure we spend that seed corn money developing the new technologies and utilizing the Russians where we can to make sure we get through the crisis. The Russians are our friends. They want to work with us. And let us—for Pete's sake, let us use a creative means of bringing down the cost and not shut off examination into, you know, alternatives on how we can supply the Space Station in a much cheaper way. Let us look at the cheap ways of doing things, and I think that was your testimony, and build upon them but using our seed corn for developing these new technologies that will push us ahead and get us out of the lap of the last generation.

With that said, I have a vote, and I will turn this over to Joe, and Mr.—I recognize Mr. Gordon, who should have more than five minutes, Joe.

MARGINAL COST OF EELVs

Mr. GORDON. Okay. We are going to have to close down here soon. There are a lot of very important questions, and I hope that we all have a chance to discuss some more after. I concur with you, Dr. Grey. I think there has been a stalling of decision. It seems that we keep pushing these decisions out, and it keeps costing us more the longer we wait. What I would at least like to do is close on one issue, and so Mr. Gregory, let me once again go back. I will try to do this quickly. I would assume that you would agree that we are going to have to continue to have both the flights of the Shuttle for the heavy lift capability until it is replaced or not needed for some reason, as well as having the Orbital Space Plane. So you are going to have to have both of them flying.

Mr. GREGORY. I think that is a fair assumption.

Mr. GORDON. Right.

Mr. GREGORY. Yes.

Mr. GORDON. All right. And NASA has told us that it is—that the marginal cost of a Space Shuttle is at $115 million. Have you been able to get that confirmed?

Mr. GREGORY. Well, from my Comptroller here, I am told that the marginal cost is 60 to 70 million per launch. The average cost, I guess this is full cost—the——

Mr. GORDON. Yeah, the 115 is full cost accounting terms. Is that what you—I am sorry. Go ahead.

Mr. GREGORY. If you will allow me to check——

Mr. GORDON. Yes, sir.

Mr. GREGORY [continuing]. With my Comptroller.

Mr. GORDON. Yes, sir.

Mr. GREGORY. The 60 to 70 is the marginal cost. It is not in full cost. And the 600 million per launch is the average cost per launch.

Mr. GORDON. But now what about the—again, we were told that 115 million per flight in full cost accounting terms. Is that not accurate? Again, I don't know these either. I mean, you are doing the proper thing to ask for help here, because I——

Mr. GREGORY. Sir, will you allow us to research that? That is not a known number to us.

Mr. GORDON. Okay. What—who told us that? Okay. We got—the Office of Space Science told us that, so we might want to get that confirmed. What—you know, I am not trying to be tricky.

Mr. GREGORY. Sir, let me add something to that number. What I gave you was a Shuttle. And when you add the payload integration into that, then the number would go up. Perhaps that is the origin of the number.

Mr. GORDON. I am just interested in what the cost of—and again, of launching it in the full cost accounting terms. The point, and then I will let you—if you are going to get back to me, we—you can get back to me with these.

Mr. GREGORY. Yes.

[The information referred to follows:]

MATERIAL REQUESTED FOR THE RECORD

Cost estimation for the Orbital Space Plane (OSP) is in progress. NASA is committed to providing responsible, credible cost and budget estimates prior to committing to new development programs. We will be following NASA policy guidelines of using the formulation phase of the OSP Program, to be completed by the end of FY 2004, to establish cost and schedule commitments for the implementation phase. At that point, the requirements and conceptual design will be sufficiently understood to ensure a responsible and credible development cost commitment is made. As part of the OSP system design process, each competing architecture contractor is providing life cycle cost estimates as a major deliverable. Government cost experts are developing cost estimates in parallel, utilizing legacy cost data from prior programs along with improved and validated cost analysis and estimating tools. A Cost Credibility External Review Team, reporting to the OSP Program Manager, is being established to provide expert assistance in ensuring credible cost estimation. In addition, an independent cost validation will be performed utilizing a Cost Analysis Requirements Document, as used by the Department of Defense and on the International Space Station Program. These various cost estimates will be studied and understood prior to the Full Scale Development decision. In addition, we are ensuring fiscal accountability on all ongoing OSP Program activities by using a proven Earned Value Management system to track actual cost and schedule performance as compared to plans.

Mr. GORDON. Also, it is my understanding that the Orbital Space Plane, you are going to have to send—you are going to have to launch it on a rocket, aren't you?

Mr. GREGORY. Yes, sir.

Mr. GORDON. Okay. And you might get some assistance here, but it is probably going to be an EELV, is that correct?

Mr. GREGORY. The crew rescue portion of the Orbital Space Plane program would be on an ELV, not an EELV.

Mr. GORDON. Okay. And what approximate cost is that going to be? What kind of marginal costs are you going to have there? Go ahead and ask your——

Mr. GREGORY. There has not—since we haven't defined what the vehicle is——

Mr. GORDON. But you know what the rocket cost is, a launch cost, that is what I am asking.

Mr. GREGORY. Okay. Just a second, sir.

Mr. GORDON. Yeah.

Mr. GREGORY. Sir, would it be possible for us to submit that for the record?

Mr. GORDON. Yes, sir. What I am trying to determine is whether there is any cost savings by having the OSP in terms of the marginal cost? There may be lots of good reasons to have OSP——

Mr. GREGORY. Including safety.

Mr. GORDON. Yeah, there may be lots of good reasons, you know, but what I am trying to get to is the marginal——

Mr. GREGORY. I understand, sir.

Mr. GORDON [continuing]. Cost. And from everything that we can—that your office, in the sense of NASA in the general sense, has provided us is if there is no marginal cost savings. And just would like to have—and you know, let me say this, too, I have got time, and so we will just keep asking and asking and asking, if necessary. And so, you know, try to make it complete, and—because you know what I want.

Mr. GREGORY. I understand, sir.

Mr. GORDON. You know. And I know that there are lots of things you don't know, what it is going to be designed, but what you can determine is it is going to be—you can determine, in all likelihood, what type of rocket it is going to take. And take the cheapest one, if that has to be, you know. Just let me know that. You know, that is all we are trying to accomplish. And again, we will just keep working on it until we get it.

Mr. GREGORY. Would it be fair, then, for me, in addition to giving you the marginal cost between the Shuttle and the rescue vehicle on an expendable ELV, to also demonstrate and show the other things that are part of this trade space as we talk about flexibility——

Mr. GORDON. Yeah, there are—there could be lots of reasons. I want to just try to get this one. You know, I mean, this is pretty hard. You know, let us get one sort of answer, and then we will go to the next. But I think—but I want more than just the rescue. I mean, we are talking about the whole OSP program.

Mr. GREGORY. Oh, the whole. Yes, sir.

Mr. BARTON [presiding]. We are going to have—we have three Congressmen——

Mr. GORDON. Yeah.

Mr. BARTON [continuing]. And we are supposed to be out of here by 1:30, and 3 times 5 is 15, and so we are going to have to be a little bit late, so we are going to ask the——

Mr. GORDON. Sure. Sure. Go ahead.

Mr. BARTON [continuing]. Ranking Member to cease the questions.

Mr. GORDON. Okay.

Mr. BARTON. And we recognize Mr. Bonner for five minutes for questions.

Mr. BONNER. Thank you, Mr. Chairman. Mr. Chairman, I come from a state that has a proud history of support of NASA, Alabama. And we are very proud of what has gone on in Marshall and in Huntsville to play a permanent role in NASA's previous success and also what we hope will be a bright future. In saying that, I am also a new Member of the Committee and a new Member of Congress, and so I am trying to understand in your strategic plan on page 25, NASA states, "We must improve our ability to deliver crew and cargo and our ability to return crew members to Earth without exclusive reliance on the Space Shuttle. New U.S.-based access to and from the Space Station is a key near-term element of the transportation plan."

Now in light of the events that have happened over the last 60 days, the tragic events, in one particular instance, I guess I am trying to understand why is it that NASA's fiscal year 2004 budget keeps us exclusively reliant on the Shuttle to deliver cargo to the Station?

Mr. GREGORY. Of course the '04 budget was written long before the *Columbia* disaster accident, and so the numbers are adjusted based on the situation at the time. We are obviously looking at all of our aspects in the run-out '05 and on out to determine what would be the appropriate funding and how it should be allocated.

Mr. BONNER. I yield back the balance of my time, Mr. Chairman. Thank you.

Mr. BARTON. The gentleman yields back the balance of his time. We would go to Mr. Lampson for five minutes.

Mr. LAMPSON. Thank you, Mr. Chairman. The reason I was asking a while ago about the cost on the X–38, I just want to make two statements on it, and then I will let you provide me the information that we asked about. One of them was from the Young study, it said that they agreed that the $1.3 billion expectation was a plausible number. I—it wasn't until November of 2002, five months after the X–38 project was canceled that we got the estimates given to this number of $3 billion to $5 billion or so. I would assume that some of the information that you will give me will at least go back and—in time before that study was done, because it wasn't until after the decision was made to shut it down that we started to get those kinds of numbers, so I would hope that that would happen.

And then I asked about the use of—or how we were going to keep our commitment between 2006 and 2010 for crew return. So let me ask my question differently, because I didn't get—I don't think I got enough of an answer. Given the prohibition on your U.S. purchase of Soyuz vehicles, how will crew rescue capability for the Space Station be provided between 2006 and 2010 and be specific. A vague answer about discussion with a partner is not acceptable.

Mr. GREGORY. At our heads of agency meeting in December in Tokyo where all of the partners came together, and at that point, it preceded the *Columbia,* so that wasn't even a part of the issue. There was a very clear gap between 2006 and when a crew rescue capability could be provided. It was agreed at that time that the Russians would provide, based on research requirements, and crew requirements, that they would provide rescue capability from that point until we had our capability within the United States for a trade or a cost to be determined.

Mr. LAMPSON. Okay. Who will pay for it?

Mr. GREGORY. For a cost and for trades to be determined. That was not part of the discussion at that point. But as far as America is concerned, there has never been, nor will there be a request to get a waiver or relief from INA. So that was also part of that agreement and well understood. Now you have——

Mr. LAMPSON. But what you are saying is that the internationals, our partners, will—or have agreed to pay for the cost of that crew return activity?

Mr. GREGORY. The partnership agreed, the partnership, including the five members of the partnership, agreed that we would all collectively depend on the Russians to provide transport and rescue and that we would determine at some time how that would be paid for or bartered for or traded for.

Mr. LAMPSON. Is there still not a plan then, I mean, that is going to be——

Mr. GREGORY. By next——

Mr. LAMPSON [continuing]. That will be determined?

Mr. GREGORY. Well, we were supposed to now have a heads of agency where we had now determined the architecture in June. Now between December and now, we had the *Columbia* accident. And so we kind of defaulted to a mode where we are maintaining the Station, because that seems to be the best thing to do until we can receive word from the Admiral Gehman's Board on how long it will take. And our next heads of agency meeting is scheduled for the end of July, and I think return to flight will be the topic of that, and the subject after that will be in your area, sir.

Mr. LAMPSON. Okay. All right. The Chairman a while ago expressed a sense of frustration. And I think that I share a great deal of that. I know that I have often talked about the purpose for a lot of the equipment that we are making, and I am not sure that we have a destination that we want to try to achieve. And consequently, we don't know what the heck we are trying to build and whether—we are going to figure out—we will build something, then we will figure out what we are going to do with it, where we are going to go with it or something of the sort. And I read an interesting sentence in your testimony, Mr. Gregory, a while ago that maybe gives me the impression that this may be where NASA is. It says, "NASA is aggressively studying longer term science and exploration goals to further provide guidance that will better inform these critical decisions." I think we are trying to study things to death and we don't have a clear vision of what we want to accomplish, and I yield back my time.

Mr. BARTON. We thank the gentleman from Beaumont. The Chair would recognize himself for the last five minutes of questions. For—oh, I am sorry. Well, as soon as I ask my questions, we will recognize the gentlelady from Houston. I am sorry. I didn't see you come back in.

Before I get into my questions, I don't want you guys to think that we don't like you folks. Okay. You know, Mr. Myers, you are a true American hero. You know, the book "The Right Stuff" could have been written about you. You know, I grew up, the seven original astronauts were heroes. I mean Gus Grissom and Wally Schirra and John Glenn and those guys, Alan Shepard. I mean, I knew Alan Shepard personally. He has, unfortunately, passed away. And my dream as a little boy was to be an astronaut. So I don't want you all to think that—I don't think this subcommittee or the Congress is down on what you have devoted your lives to. I don't think we are trying to second guess too much some of the basic decisions, but at least in my case, you know, I want to try to help recapture the vision that made it possible to put a man on the moon in less than 10 years. If we could do that in the '60's with the technology base then, you know, and given the fact that we had Vietnam going on. And we had a transition in our civil rights in this country; we had a lot of problems in this country back in the '60's. But in spite of that, we put the resources and the technology to put a man on the moon, an American, not just a man, but a United States citizen on the moon. And I don't view trying to keep that era's technology flying for another 10 or 15 years to be an adequate vision. I just don't do it.

UNMANNED SHUTTLE

So my first question is to you, Dr. Grey. In your testimony, you elude to using the existing Orbiter fleet in an unmanned capacity. Now I am not—I don't want to put the Orbiter back up with men and women on it, I just don't think it is safe, and I don't think you could make it safe. I don't attribute that to a lack of leadership at NASA. I just don't think the technology can be made safe. But Congressman Gordon, the Ranking Member, has pointed out to me that we need some heavy lift capacity if we are going to try to use the Space Station in a meaningful way. Could we make the Orbiter an unmanned Orbiter so that we could still use it and if we lost one, we just lost hardware, we didn't lose human life and start on a new technology Space Plane or an Orbiter that was manned? Is that technically possible? And if it is, do you have any kind of a timeline and a cost estimate for that?

Dr. GREY. I believe it is technically possible. The current Orbiter has flown through about, I would say, 98 percent of its mission without a pilot at the controls. The only time manual control is used today is in Space Station proximity operations and in the final phase of landing the craft. Both of those tasks can be accommodated by computer-operated systems. The Progress and Soyuz dock at the Space Station with nobody handling the controls. The Russian Buran shuttle 10 years ago was able to land automatically. And I believe our Shuttle is equipped to do that, except we have a pilot overriding it.

So in terms of operating the Shuttle autonomously, yes. The problem comes if we want the Shuttle to carry humans, then we still must go through the same safety provisions that we are doing today. If we are flying only cargo, the cost of running a Shuttle flight could be considerably less, because we could significantly reduce the infrastructure and the safety imposed operations that are now required by having people on board.

Mr. BARTON. And Mr. Gregory, what is your response, as the senior NASA person here, if the Congress directed you the appropriate fashion, not you personally, but the agency to follow-up on what Dr. Grey eluded to. What is your response to that?

Mr. GREGORY. Well, as long as it is not near-term, we wouldn't come to ask for negotiation. But in the future, if you look at as we move from removing the humans, reducing the risk to humans into something that is safer, at least in the ascent phase, you would begin to look at what is a minimum crew on a Space Shuttle.

Mr. BARTON. Well, now don't misunderstand. Let me—I don't want any more people going up in the existing Orbiter fleet, period. I am talking about, if I understood Dr. Grey correctly, an unmanned Orbiter. And if we want to use the Soyuz or use the Russians to put some Americans up in the Space Station, so be it. But I am talking about no more Americans going up in the existing Orbiter, no more people, period, but using it in an unmanned fashion and then taking whatever the resources that we free up, plus additional resources to build a new manned Space Plane or Orbiter. That is what I am——

Mr. GREGORY. Well, what I was trying to do is kind of walking through a sequence on how you would get there.

Mr. BARTON. And do it quickly, because my time, unfortunately, has expired.

Mr. GREGORY. Okay. You would move from a full crew complement down to, perhaps, a pilot and co-pilot, provide escape mechanism for them. And then you would begin to look at the Orbiter in a cargo sense where you would then use such things as the technology demonstrations that we are working on right now, the DART, as an example, with the Rendezvous technology. And perhaps evolve the Shuttle into an autonomous cargo up and back capability.

Mr. BARTON. I am going to encourage Chairman Rohrabacher and Ranking Member Gordon to join me in sending a letter, or I don't know the appropriate way to do it, but that we formally ask that NASA investigate that.

My time has expired. I would now like to recognize for the last rounds of questioning, the gentlelady from Houston, Ms. Jackson Lee.

Ms. JACKSON LEE. Thank you very much, Mr. Chairman, and I appreciate very much the line of questioning of Mr. Gordon and where we are in this question of the safety question. And I guess I would like to go back to that and address Dr. Grey and Mr. Myers and Dr. Griffin and others. What is your response to the question of putting the horse before the cart, the idea of if we—having the International Space Station as a focal point? If we know that we need to have a vehicle that deals with crew transport and cargo transport, shouldn't it be the approach to be able to look at what we want to do first before we design a vehicle? And then isn't it important—isn't it imperative that we have precise understanding of the safety factors that would bring about a statement that the OSP would have a requirement to be safer than the Shuttle or the Russian Soyuz? And we seemingly can not pinpoint that that is actually accurate. What is your assessment, Dr. Grey?

Dr. GREY. In response to the last question, I think the numbers stand for themselves. Regardless of how you compute safety, the Shuttle has a demonstrated failure rate of 2 in 113. The Soyuz has a demonstrated failure rate of 2 in, I believe it is, 86. So you know exactly what the historical failure rate is. That doesn't mean that is the projected failure rate. That could be different. So if that is what we are dealing with, you know what the numbers are.

Now in terms of defining the mission, I fully agree it is essential to define what we are going to use these vehicles for. The Orbital Space Plane's job is to service the Space Station: first with crew rescue, secondly with crew supply and cargo supply. The Space Station's life is limited. Let us hope it will last until 2020, perhaps, but certainly not much longer than that. What are we doing about the next generation? We have a lot of missions we would like to pursue. We would like to go to the moon. We would like to go to Mars. We would like to improve the safety factor of our present vehicles. There is where the Next-Generation Launch Technology program comes in. It should be doing the risk reduction necessary for us to make a decision as soon as possible on what the next generation vehicle is going to be for its uses. And——

Ms. JACKSON LEE. But obviously we have to include safety in that analysis as well.

Dr. GREY. Oh, yes. I think safety is a key factor in some of the things that have been discussed. For example, providing escape capability from the Shuttle for all modes of flight or from the Orbital Space Plane for all modes of flight is a key factor in those designs.

Ms. JACKSON LEE. Well, keeping—let me just say, keeping in synch with the general theme that I have utilized over these years as a Member of this committee. I am very concerned that even with the numbers that there is still not a—if you will, a coming around the issue, getting your hands around the issue of the safety issue—safety point. And that, to me, conflicts with where we are going in terms of a very effective design of the Orbital Space Plane. But until we answer those questions, I guess to my satisfaction, maybe I should say that, maybe the numbers are 2 in 113 and 2 in 86 are not helpful, because I want a projected analysis of what that frankly means. Until we do that, I think that we have a lot of work to do, and I would encourage NASA to do so.

And I would encourage you, Deputy Administrator Gregory, to be in touch with those of us who are concerned, and I look forward to hearing with—hearing from you and meeting with you. And I thank the panelists for their testimony. And I yield back.

Mr. BARTON. We thank the gentlelady. We have one more question that Subcommittee Chairman Rohrabacher asked that I ask. We would like a little more definition on your budget estimate. I think your testimony indicated that it was just a placeholder, so we would like for you to give us, on the record, in writing, as much definition as you can on that budget and with specifics about what you think the OSP would actually cost. So you don't need to respond to that, just Congressman Rohrabacher asked that I put it in the record.

All Members of the Subcommittee will be allowed to put additional written questions to this panel. And if they do so, we would ask you gentlemen to please respond as quickly as possible. We intend to aggressively oversee the ongoing investigation and also to oversee the, perhaps, new definition of a new vision for NASA. And again, I want to commend you for what you all have done in the space program. You all are all great Americans, and especially Mr. Myers for what you did in the Apollo program. It is really the best of what America should be all about. With that, this hearing is adjourned.

[Whereupon, at 1:35 p.m., the Subcommittee was adjourned.]

Appendix 1:

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by Frederick D. Gregory, Deputy Administrator, National Aeronautics and Space Administration

Questions submitted by Chairman Dana Rohrabacher

Q1a. Your written testimony states that the budgets for the Orbital Space Plane (OSP) are "placeholder estimates only."

What specific steps is NASA taking to develop and refine a cost estimate for the OSP?

A1a. We are following NASA policy guidelines of using the formulation phase of the OSP Program to establish cost and schedule commitments for the implementation phase. As part of the OSP system design process, each competing architecture contractor is providing life cycle cost estimates as a major deliverable. Government cost experts are developing cost estimates in parallel, utilizing legacy cost data from prior programs along with improved and validated cost analysis and estimating tools. An Independent Cost Estimate will also be performed prior to a full-scale development decision in late FY 2004, and a Cost Assessment Requirements Document (CARD) will be developed to support this independent estimate.

A preliminary estimate of the OSP costs is being developed in support of the FY 2005 budget process, with particular attention placed on the FY 2004 and FY 2005 budgets. This estimate will be available in support of the FY 2005 President's Budget.

Q1b. Will NASA have a better estimate of the cost of the OSP later this year to support deliberations with OMB and Congress? If so, when will this estimate be available? If not, will the FY 2005 budget contain "placeholder estimates only?"

A1b. Yes. A preliminary estimate will be available in support of the FY 2005 President's Budget. The NASA cost and schedule commitment for the implementation phase of the OSP Program will be provided at the end of formulation, per NASA policy guidelines.

Q1c. Will a Cost Assessment Requirements Document (CARD) be developed for the OSP? If so, when will a baseline CARD be established?

A1c. Yes. An independent cost validation will be performed utilizing a Cost Analysis Requirements Document. The baseline CARD will be established by the full scale development decision-point at the end of FY 2004.

Q1d. Will NASA seek help from the Defense Department or any other outside agencies in developing a cost estimate? If so, what will their role be? If not, why not?

A1d. Yes, the Cost Credibility External Review Team (CCERT) supports the independent cost credibility team with membership that includes DOD CAIG, RAND, Aerospace, Air Force, and the External Program Assessment Team (EPAT).

Q2a. How many flights of the OSP do you expect over the life of the Space Station program?

A2a. At this time, the total number of flights to the ISS has not been determined. The final number will depend upon the configuration chosen for OSP, the projected life of the ISS, and ISS crew size. The OSP Level I requirements state a minimal rotation of 4–6 months and a crew size of up to 4 persons. Based upon ISS lifetime of 2016, and a crew rotation every 6 months beginning in 2010 for the first flight of the CRV, a minimum of 14 flights would be required.

Q2b. If this is not known, how will you calculate life cycle cost, since a key Level 1 Requirement is to "minimize life cycle cost?"

A2b. The three prime contractor teams will present their respective vehicle and operational concepts at the System Requirements Review scheduled for later this year (October 2003 timeframe). Each team's estimate to design, develop, and operate their system will be based upon a documented set of assumptions including flight rates and projected life of ISS.

Q3a. The Committee asked you to address "what areas of the proposed approach pose the greatest risk and how does NASA plan to reduce these risks?" Your testimony provides a very general answer: "our approach to mitigating these risks is to consistently address the issues using an integrated approach within the framework of the ISTP."

Please provide a more complete answer that identifies specific risks to the program and plans for reducing those risks.

A3a.

1) Risk: Failure to establish OSP Level 2 Requirements in a timely manner.

Mitigation: The OSP Program has established a detailed schedule of activities to develop and approve the Level 2 Requirements by the Systems Requirement Review. Leads are assigned to each task. Review teams have been established and are conducting multiple review cycles of the draft Requirements documentation. The Program Manager is tracking progress, relative to the schedule.

2) Risk: At the end of the Formulation Phase, the identified development cost exceeds expectations.

Mitigation: We are following NASA policy guidelines of using the formulation phase of the OSP Program to establish cost and schedule commitments for the implementation phase. As part of the OSP system design process, each competing architecture contractor is providing life cycle cost estimates as a major deliverable. Government cost experts are developing cost estimates in parallel, utilizing legacy cost data from prior programs along with improved and validated cost analysis and estimating tools. A Cost Credibility External Review Team, reporting to the OSP Program Manager, is being established to provide expert assistance in ensuring credible cost estimation. In addition, an independent cost validation will be performed utilizing a Cost Analysis Requirements Document, as used by the Department of Defense and on the ISS Program. These various cost estimates will be studied and understood prior to the Full Scale Development decision. In addition, we are ensuring fiscal accountability on all ongoing OSP Program activities by using a proven Earned Value Management system to track actual cost and schedule performance as compared to plans.

3) Risk: ELV proves incompatible with the OSP Level 1 and 2 requirements.

Mitigation: The ELV designs are being reviewed to understand their projected reliability, failure modes, and potential areas of improvement. The OSP contractors are developing concept designs to ensure the OSP weights and loads are compatible with the dynamic environment of the ELV. A Probabilistic Risk Assessment Tool is being developed to understand the failure modes and safety implications of the system.

4) Risk: Concept studies identify the requirement for additional flight demonstrations.

Mitigation: The OSP contractors are developing vehicle design concepts, including an assessment of the technology development needs for the concepts. The flight demonstration projects are being evaluated to ensure they are addressing these needs.

Q3b. What specific technologies must be demonstrated with the X–37 that cannot be analyzed tested or simulated adequately on the ground to bound the parameters of its use in space?

A3b. Analysis and ground testing cannot fully simulate the actual combined, flight environments of a space mission. Flight-testing in the applicable environments provides verification of performance results to minimize risk. Extrapolation of analyses, including ground tests, in certain key areas such as aerothermal predictions can result in as much as a 25 percent uncertainty factor. Current flight test aerothermal experience is limited to the Shuttle database, and is configuration (weight, size, etc.) dependent, with limited instrumentation. Flight tests such as X–37 address the need to demonstrate different design solutions, and add to the limited database with substantial instrumentation, without placing human life at risk.

Ground facilities cannot fully replicate the actual combined flight environments since this would require duplication of the on-orbit and atmospheric environments and associated transitions. Such duplication would be infeasible physically and cost prohibitive. For example, thermal protection system (TPS) ground test facilities are limited to Mach 8 and the corresponding temperatures. A flight test from orbit provides the only actual re-entry environment for the combination of temperature, pressure, and loads, including structural and thermal (i.e., heat rate, heat load) through the entire Mach regime. Thus, complete verification of TPS performance can only be accomplished by flight test from orbit for exposure to the full re-entry heating environments.

Another example of the need for flight tests is the autonomous guidance, navigation and control (GN&C) system. GN&C can be exposed to extensive ground testing but only a test of all phases of flight, from orbit to final controlled wheel stop, can exercise the algorithms used to verify performance in the combined environments and solve the natural and mechanical dispersions of any re-entry.

Q4. Please provide the basis for the 25 percent uncertainty factor stated and the method used to derive this figure. What specific parameters does this predicted uncertainty apply to? Explain why this uncertainty factor could not be included in the predicted aerodynamic, thermal, and mechanical loads to derive the worst case predicted environmental loads.

A4. The uncertainties were determined by comparison of LaRC Navier-Stokes heating predictions using the LAURA code and available experimental ground and flight test data. The 15 percent uncertainty on the windward acreage heating was developed from extensive ground test comparisons with test models for the X–33, X–37, X–38, the Shuttle, current planetary configurations and several vehicles in the past. The comparisons also include STS–2 flight heating data from a study performed approximately 10 years ago and recently from benchmarking efforts during the STS–107 investigation. These flight comparisons are at high velocity entry conditions, and thus include any chemistry effects associated with orbital entry conditions. From the ground and flight test heating data comparisons with the corresponding predicted results, we can demonstrate that the discrepancies are within 15 percent. While the X–37 will be at slightly different flow conditions, the Shuttle heating comparisons give us a very strong confidence in stating a 15 percent uncertainty at flight conditions.

For the wing leading edge region, the database is very, very limited. Most ground test models are tested at too small a scale to make accurate measurements on the very thin leading edges, and there are no leading edge flight heating data that exist similar to the Shuttle acreage data. To provide some confidence in the X–37 wing leading edge heating predictions, comparisons were made with a ground test of a large Shuttle model tested at CALSPAN in the mid 70s. These comparisons have shown discrepancies of approximately 18 percent. Unlike the general acreage heating database, we don't have a wide range of configurations/flow conditions at ground test conditions. Also, we do not have the flight data to give us insight into the effect of chemistry on wing leading edge heating. The wing leading edge region is a far more complicated flow region to resolve than a windward surface due to the shock-shock interaction. Thus, we have placed a 25 percent factor on the heating uncertainty.

Q5. NASA has not decided on an OSP concept (mini-Shuttle, lifting body, or capsule; or decided whether it will be reusable vs. expendable). Given that these key parameters have not been decided, and the statement above that re-entry loads are configuration dependent and only an actual re-entry flight can exactly duplicate the environment (and since NASA asserts that ground testing would be physically infeasible and cost prohibitive), what is the rationale for flying a specific vehicle configuration (X–37) which will almost certainly not be the same configuration as OSP (weight, size, etc.)?

A5. The X–37, while a specific configuration, allows collection of flight data for a known configuration, trajectory, and resulting combination of loads. The data allows correlation of analytical models, which can be used for a variety of configurations, and load conditions.

These flight conditions in terms of temperature, pressure, and loads will serve to bound re-entry conditions expected for an actual OSP configuration. The TPS technologies demonstrated will be applicable to any OSP configuration, whether it is winged, lifting body, or a capsule, and would also have applicability to Next Generation Launch Technologies and National Aerospace Initiative.

It is also true that the X–37 configuration will certainly be different from an actual OSP. However, it is the weight and size of the X–37 that makes it an excellent flight demonstrator for advanced high temperature, more durable TPS technologies. The re-entry weight of the vehicle will approach 7500 lbs. with a wingspan of only 15 ft. The re-entry flight profile will cause the wing leading edge surfaces to approach 3000 degrees F.

Q6. What levels of uncertainty would the variation in configuration introduce as compared to the level of uncertainty introduced if the exact configuration were known and could be ground tested?

A6. Ground testing of the combined load conditions is not feasible in ground test facilities. The variation in configuration can be assessed by analysis, using analytical models correlated to flight test data. The uncertainty level from configuration changes is much less than the uncertainty level of material samples tested in ground test facilities in less than the combined load conditions.

Q7. Is a real flight test of the wrong configuration, better than a ground test with the right configuration? What would the difference in cost be?

A7. Yes. Ground testing of the combined load conditions is not feasible in ground test facilities. The variation in configuration can be assessed by analysis, using analytical models correlated to flight test data.

Q8. Why does NASA not include Mercury, Gemini, Apollo, and Soyuz in its statement that aerothermal flight experience is limited to Shuttle? Are the aerothermal data available from these past missions?

A8. Aeroheating data is available from these past programs. NASA's knowledge of entry environments evolved from Mercury through Apollo and has been extended during the Shuttle Program. Flight tests such as the X–37 add to the database with substantial flight instrumentation in representative flight environments. The statement that current flight test aerothermal experience is limited to the Shuttle database was meant to convey that this is the only data available from a reusable reentry space vehicle.

Q9. Does NASA's use of the phrase "wheel stop" imply that the design will land horizontally and have wheels, landing gear and brakes?

A9. For X–37, the term "wheel stop" does imply that the design lands horizontally and has wheels, landing gear and brakes.

Q10. The team chartered by NASA to make a top-level assessment of the viability of using Apollo-derived Command and Service Modules (CSM) as the basis for a Crew Return Vehicle (CRV), and potentially for a Crew Transfer Vehicle (CTV) for the International Space Station concluded unanimously that an Apollo-derived CRV concept, with 4- to 6-person crew, appears to have the potential of meeting most of the OSP CRV Level 1 requirements. An Apollo derived CTV would also appear to be able to meet most of the OSP CTV Level 1 requirements with the addition of a service module. It further concluded that using the Apollo CSM as an ISS CRV and CTV has sufficient merit to warrant a serious detailed study of the performance, cost, and schedule for this approach, in comparison with other OSP approaches, to the same Level 1 requirements.

Has NASA pursued a serious detailed study of the performance, cost and schedule for this approach? If not, why not? If such a study is underway, when will the results be available?

A10. Yes, as part of the independent cost estimate development, and the on-going OSP to ISS mission model study, NASA has evaluated the capsule derived concepts against multiple winged vehicles. The final results will not be available until after the Systems Requirements Review later this year.

Q11a. Your testimony indicated that NASA would, "perhaps evolve the use of the Shuttle into an autonomous cargo up and back capability." Dr. Grey's testimony stated, "The only time manual control [of the Shuttle] is used today is in Space Station proximity operations and in the final phase of the landing. Both of those tasks can be accommodated by computer operated systems."

Does NASA intend to pursue a fully autonomous Shuttle capability? If not, why not?

A11a. A fully autonomous Shuttle capability, along with other strategic options, is being considered to support the Integrated Space Transportation Plan. Currently, the ISTP is being reevaluated in light of the *Columbia* accident.

Q11b. What issues would have to be addressed to develop a fully autonomous Shuttle capability to service the Space Station?

A11b. Major changes to the Shuttle's software and hardware systems would be required to provide autonomous rendezvous and docking capability to the ISS. A new docking mechanism would also have to be developed for the ISS. Because of the magnitude of the design, development, and testing required to implement autonomous capabilities; a cost-benefit analysis will be required before commencing work.

Q11c. What studies have been performed by NASA or by contractors in the last five years to assess the desirability and cost required to develop:

- *The Shuttle's autonomous proximity operations capability, and*
- *The Shuttle's auto-land capability?*

What are the criteria for these studies? What are their results?

A11c. While neither NASA nor industry has conducted a study of Space Shuttle autonomous proximity operations or auto-land capability in the last five years, we believe that the concept is sound. Design studies would be instituted if NASA chooses to develop such a capability.

Q11d. What studies has NASA performed at any time to arrive at the conclusion that "the concept is sound" for autonomous proximity operations and auto-land capability? Please provide a list of these studies.

A11d. Previous Studies:

1976 Unmanned Flight Capability (Rockwell)

1986 New Unmanned Orbiter (Rockwell)

- Initiated to identify gains with an unmanned orbiter to continue the orbiter flight schedule during the stand-down period following STS–51

1986–1988 Unmanned Orbiter (Rockwell)

1986–1988 NASA Unmanned Shuttle (NASA)

- Detailed study led by DA8/A1 Pennington
- 24-hour flight duration with IUS/TDRS deploy
- Modified OV 102 vehicle to support dual manned or unmanned capabilities
- Vehicle modification and operations/training impacts assessed
- Did not include autonomous docking methods or concepts

1987–1988 Unmanned Orbiter Design Reference Missions and Automation of Manned Functions (Rockwell)

1989 Orbiter Mixed Fleet Strategy (NASA)

1989 Unmanned Orbiter (Rockwell, IR&D #89104)

- Developed unmanned orbiter and remotely piloted orbiter mission requirements
- Select preferred concepts for implementing this capability

1990 Fully Automated Shuttle Transportation (Rockwell)

1992 Automated Orbiter Requirement Definition Study (Rockwell, IR&D #10201)

- Partially completed study due to lack of funding
- Products include Requirements Definition Document (RDD), Trade Analysis and Risk Assessment

1993 The Reusable Cargo Vehicle (RCV) Delivers Increased Cargo To and From Space (Rockwell)

- Study assessed modifications to existing orbiter fleet
- Removed systems necessary for manned capabilities and adds systems necessary for unmanned capabilities
- Removed crew cabin, provisions and associated consumables
- Added in automated capability
- Relocated equipment for payload CG enhancement
- Addressed RNDZ and docking operations at a high level
- Results: RCV satisfied delivery requirements, used existing Shuttle components and launch/landing facilities, some development risk, and test bed for Shuttle evolution elements.

Current Studies:

As an element of the Shuttle Service Life Extension Program (SLEP), United Space Alliance is being tasked perform an Autonomous Shuttle study. Tasks to be performed in this study are to review, consolidate and summarize previous autonomous studies in the areas of:

- top-level requirements and types of missions/draft reference missions (DRMs) that an Autonomous Shuttle will perform;
- concept of operations;
- design concept/implementation trades;
- design concept/implementation analysis completed and remaining, and;
- rough-order-of-magnitude cost estimate and implementation schedules.

Q11e. What were the results and conclusions of those assessments? (Crew escape studies by NASA, USA, and Boeing)

A11e. Several of the options were deemed technically viable. However, none could meet the requirement for providing escape for a seven-person crew nor could they be incorporated into the Shuttle fleet by 2005.

Q11f. Why was incorporation into the fleet by 2005 considered a requirement? How many crew could flown with the crew escape systems studied? What were the cost estimates for each of these crew escape systems?

A11f.

- Guidelines for 1999 studies were based on a Shuttle replacement in 2010 timeframe. Upgrades needed to be incorporated by 2005 so that they could be used for at least five years before Shuttle replacement.
- The concepts considered technically feasible could accommodate four to six crew.
- The costs for the various feasible systems ranged from $1.2 to $4 billion.

Q11g. What additional development and testing is needed to implement the Shuttle's autoland capability?

A11g. Should auto-land capability be deemed a requirement for the Shuttle, a complete definition, design, development, and testing program would be required.

Q12a. In Dr. Grey's written testimony he suggests converting the Shuttle's four-person flight deck into an escape capsule suitable for egress during all flight modes.

Has a similar crew escape method been evaluated and what were the conclusions?

A12a. Crew survivability has been studied continuously since the *Challenger* accident in 1986. The scenario described by Dr. Grey was not one of the options considered because NASA only reviewed options that would provide crew escape capability for the entire crew.

Q12b. What other crew escape methods and systems have been studied by either NASA, contractors, or by independent groups?

A12b. In 1999, the Orbiter Project together with the United Space Alliance and Boeing Company studied 11 different crew escape concepts including ejections and extraction options. The guidelines for the concepts included: using a seven-person crew as the model; incorporating the changes into the fleet by 2005; and only studying options for crew escape during the ascent phase of the mission.

Q12c. What were the results and conclusions of those assessments?

A12c. Several of the options were deemed technically viable. However, none could meet the requirement for providing escape for a seven-person crew nor could they be incorporated into the Shuttle fleet by 2005.

Q13. If a decision were made to phase-out the Space Shuttle as soon as construction of the Space Station was completed, including the international elements (International Core Complete), what is the minimum number of Space Shuttle flights necessary to achieve International Core Complete?

Please provide a schedule (manifest) identifying each of these Shuttle flights, as well as all other supporting launches, such as Progress, Soyuz, and ATV vehicles over this period. Please clearly identify any assumptions regarding the use of Russian (or other international) or commercial capabilities.

A13. According to the current manifest, a minimum of 25 Space Shuttle missions will be required to achieve assembly of the remaining International Partner elements. The flight schedules prior to the *Columbia* accident on February 1, 2003, for completion of the U.S. Core (Attachment 1) and the accommodation of the International Partner elements (Attachment 2) reflect all Space Shuttle ISS assembly missions and flights of the European Automated Transfer Vehicle (ATV) and the Japanese H–II Transfer Vehicle (HTV). Russian Soyuz and Progress vehicle missions are not included on the attachments. Currently, two Soyuz and four Progress missions are planned in 2003 and two Soyuz and five Progress missions are planned in 2004. Implementation of this launch schedule by Rosaviakosmos is contingent upon the identification of additional funding by the Russian Government later this year.

An updated ISS manifest will be determined when a Space Shuttle return to flight date is established, along with updated utilization, ISS logistics and maintenance requirements.

Q14a. What is the definition of "definitive medical care" as used in the OSP Level 1 requirements?

How did NASA arrive at the requirement to "provide ongoing medical treatment to the crew until arrival at definitive medical care within 24 hours?"

A14a. The definitive medical care requirement was based upon the input of NASA's Chief Medical Officer. "Definitive Medical Care" is interpreted as meaning the treatment of aspects of de-conditioning, illness, and/or injury of a crew member such that the patient's condition can be improved rather than just stabilized. "Within 24 hours" is interpreted as meaning the time from decision to return form the ISS until arrival at the appropriate medical facility.

Q14b. What are the minimum requirements in terms the type of medical facility (i.e., what level trauma center or other recognized category of medical facility or capability) that is necessary to meet the definition of "definitive medical care."

A14b. The definitive medical care requirement was based upon the input of NASA's Chief Medical Officer in consultation with the Astronaut Crew Office and the OSP Program's Requirements Development Team. As stated in the Draft Orbital Space Plane (OSP) Level II System Requirements Document issued 1 August 2003, the Medical Care facility must possess medical capability equivalent to a tertiary care/ Level I hospital (trauma and neurosurgery capabilities) with a hyberbaric chamber facility.

Q14c. Would NASA revise this requirement if it turns out to be a major cost or schedule driver?

A14c. We view the Level 1 requirements to be a living document, and can be changed during formulation. If a requirement is determined to be a major cost or schedule impediment, it will be reviewed for change at the Agency level.

Q14d. Will the OSP be owned by the government and operated by a contractor, as the Shuttle is, or will it be privately owned and operated, as stated as one of the original goals of the Space Launch Initiative?

A14d. This decision has not been made at this time. Because of current limited market opportunities, the most likely scenario would be that the OSP would be government owned and contractor operated. The final operation concept will be determined after System Requirements Review (SRR) this fall.

Q14e. If the government is to own the vehicle, why did NASA change its philosophy on this?

A14e. As stated above, the final policy decision has not been made at this time. The original writing of the ISTP, the launch market was much different from today. Due to low market demand, there is currently not sufficient commercial interest in a crewed space vehicle to support a commercially-owned vehicle.

Q15a. Russia is expected to complete its obligation to provide crew rescue capability for American astronauts using the Soyuz capsule in 2006. The International Space Station Management and Cost Evaluation (IMCE) task force recommended that the 2006 crew rescue problem must be resolved before they considered the ISS Core Complete as a credible option. Even with optimistic assumption the OSP won't be ready until at least 2010. NASA has not clearly explained how it plans to handle the problem of emergency crew rescue for American astronauts in the interim.

How will the Space Station program handle crew rescue needs while pursuing the development of the OSP?

A15a. At the December 2002 ISS Heads of Agency meeting in Tokyo, the ISS Partnership agreed to pursue a configuration option that, calls for increasing the size of the ISS crew beyond three beginning in 2006–2007 timeframe to meet the ISS utilization and resource requirements that had been re-validated in 2002. At this meeting, the Partners agreed that crew rescue for the increased crew would initially be provided by additional Soyuz crew rescue vehicles and eventually by both Soyuz and the Orbital Space Plane. Any specific Soyuz vehicle requirements and financial arrangements will be developed as part of the process of resolving ISS configuration issues. All of the ISS Partners recognize that the solution must be consistent with U.S. law regarding funding for NASA's human space flight activities. The Partnership had planned to complete this process by December 2003, but the loss of Space Shuttle *Columbia* in February 2003, interrupted the multilateral work on these ISS configuration issues, including those related to the provision of crew return capability beyond a crew of three. A meeting of the ISS Heads of Agency will be held in late July 2003 to discuss how this process can be reinitiated based the current plans for the return to flight of the Space Shuttle.

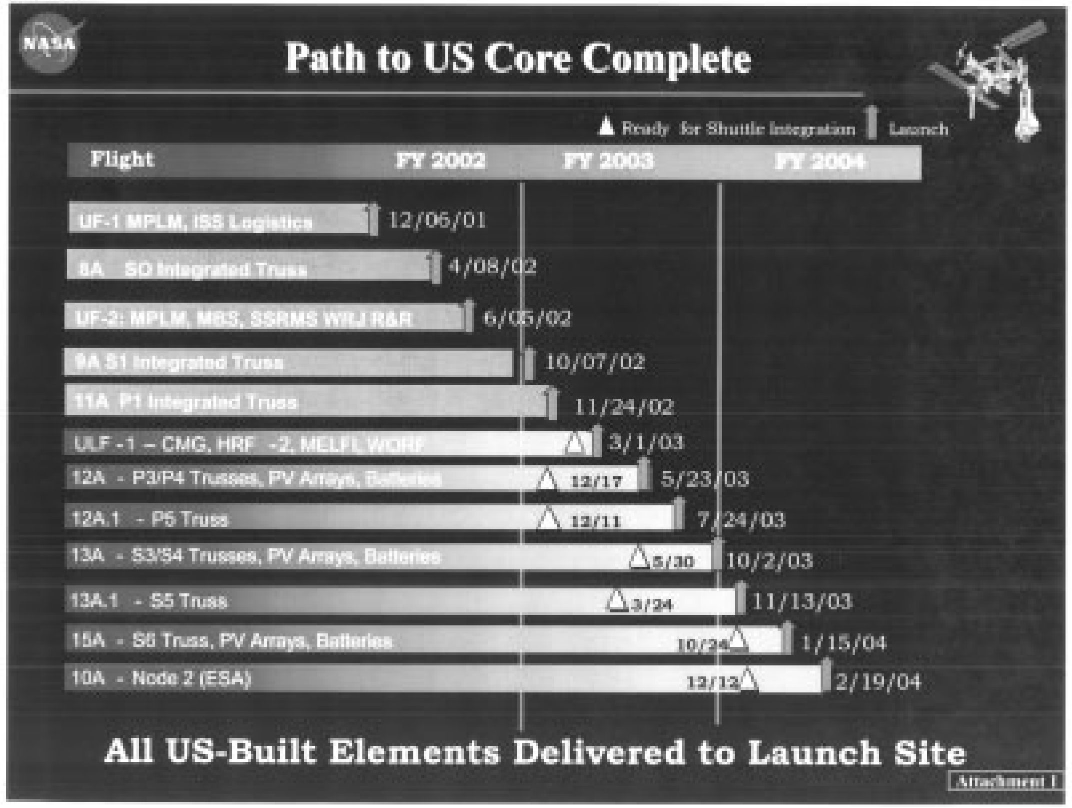
Q15b. What promises has NASA made to the Russians to secure their cooperation to provide the Soyuz services for American astronauts after 2006?

A15b. NASA has made no "promises" to Russia to secure Soyuz vehicles post 2006. The ISS Partnership is addressing the requirements for accommodation of crew rescue capabilities after 2006 as part of the ISS Program Action Plan, established at the Tokyo 2002 Heads of Agency meeting. All of the ISS Partners recognize that any solution related to ISS crew rescue must be consistent with U.S. law.

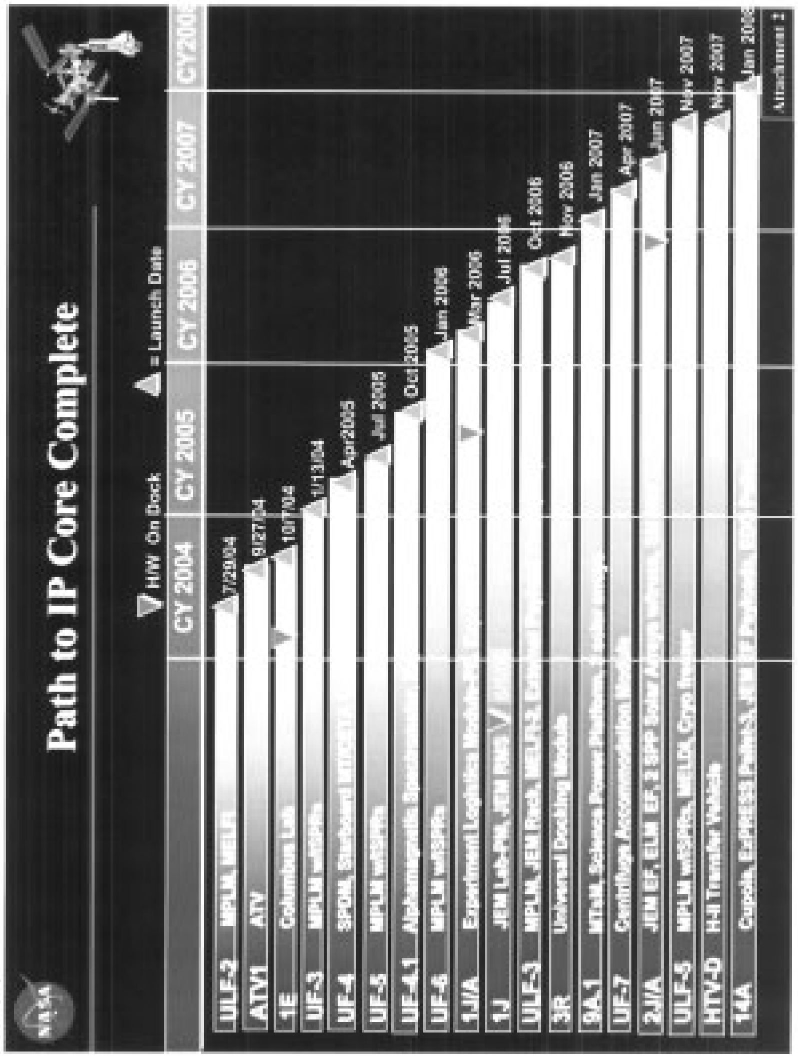
Q15c. Given the recent experience of the Soyuz capsule landing more than 275 miles away from its intended target, has NASA reconsidered the use of the Russian Soyuz for this purpose?

A15c. No. The Soyuz is an extremely reliable spacecraft and our crews are well trained for its operations. The U.S.-Russian Stafford-Anfimov Joint Commission has been tasked to assess the Russian investigation of the Soyuz TMA–1 landing of the ISS Expedition 6 crew on May 4, 2003 and report to NASA and Rosaviakosmos on this matter before the planned landing of the Expedition 7 crew later this year. As a result of the Soyuz landing, however, NASA and Rosaviakosmos have already sent a GPS receiver and satellite phone to the ISS to facilitate crew location on future Soyuz landings. NASA is confident that the Soyuz TMA–2 docked to the ISS is safe.

Attachment 1



Attachment 2



Questions submitted by Representative George R. Nethercutt, Jr.

Q1a. The Mission Needs Statement for the Orbital Space Plane (OSP) indicates that the vehicle shall initially launch on an Expendable Launch Vehicle (ELV). It seems likely that the vehicle of choice will be the Evolved Expendable Launch Vehicle (EELV).

Is there any reason we should not utilize the EELV to support this program?

A1a. OSP's Level 1 requirement refers to an ELV in the generic sense, not a specific vehicle or class of vehicle. NASA will not restrict industry by pre-selecting a class of vehicles—the trade space remains open to all ELVs. The final vehicle/launcher configuration will not be known until the OSP concept has been selected. The ultimate drivers for selection of an ELV will be the dry weight of the OSP, including shroud if required, and the cargo payload capability of the OSP.

Q1b. Is it necessary to human-rate the EELV?

A1b. NASA will human rate the ELV, as part of the entire system including the spacecraft and its crew abort and survival systems. Modifications will be incorporated to make these vehicles safer than the Space Shuttle and the launch vehicles supporting Soyuz, which is an OSP Level 1 requirement.

Q2a. Are four variants of the EELV envisioned (two human rated, two cargo-rated), or would the modifications for human-rating the vehicle become the standard design for both versions of the EELV?

A2a. Again, NASA will not restrict industry by mandating the OSP design. The operational concepts remain part of the ongoing trades and analyses. The Level I requirements allow for a single or multiple vehicles to meet the mission needs. As stated above, NASA will human rate the ELV as part of the entire system(s).

Q2b. If so, what modifications would likely be necessary and how much would these changes cost the program?

A2b. It is impossible to define all modifications that may be required until the final vehicle and operational concepts have been selected. The major changes will include the modifications required to provide crew access and egress capabilities to the existing launch complexes. The cost impacts, which will vary depending on the concept selected, are under evaluation by the OSP Program.

Q3. Which agency, the Air Force or NASA, would bear the cost of these modifications and the recurring costs associated with a more expensive launcher? Please estimate the recurring costs associated with the modifications.

A3. NASA will bear the costs associated with any modifications to the ELV's that are uniquely required for the OSP. We cannot estimate recurring costs until the OSP concept is determined, as well as the completion of studies to determine what modifications will be required.

Q4. Is there sufficient price elasticity in the commercial market to absorb this additional marginal cost for each flight of the EELV?

A4. At this stage, it would be premature to speculate on the impact on the commercial market. We anticipate that the improved reliability of OSP will enhance the competitiveness of U.S. suppliers.

Q5. Please provide a detailed explanation of joint NASA–DOD research and technology demonstration activities associated with the OSP. What commonality exists between DOD's programs to assure access to space and the OSP?

A5. The level of cooperation between NASA and DOD is higher now than anytime in the last decade. While the purpose of the OSP Program is to develop a crewed vehicle for NASA missions only, there are some elements within the Program that are of mutual interest to NASA and DOD. For example, the Demonstration of Autonomous Rendezvous Technology (DART), Project, is demonstrating advanced video guidance technology needed for autonomous (no-pilot) approach and capture between two vehicles in space. This technology is needed for the OSP Program and is also being used in the DARPA Orbital Express Program. In addition, the X–37 vehicle is demonstrating technologies that are of potential interest to both NASA and DOD missions.

Questions submitted by Representative Frank D. Lucas

Q1. Would you entertain proposals to meet the cargo and crew transfer needs for ISS under pure commercial services contracts, rather than building dedicated government vehicles to meet the same needs? Please explain your answer and the assumptions.

A1. NASA's Space Architect is leading a comprehensive review of the Integrated Space Transportation Plan (ISTP). The role of domestic commercial suppliers for crew and cargo transfer in support of ISS requirements is a part of this review. In the event there are changes to NASA's ISTP investment strategy, they will be reflected in future budget proposals, and briefed to stakeholders as part of the budget process.

Q2. Have you explored any development synergies or potential cost savings with other space plane development efforts such as the DARPA RASCAL program or the commercially developed suborbital tourism and X-prize vehicles? If not, why not?

A2. No. NASA begins with requirements needed to complete our missions. The Agency is now defining those requirements for the Orbital Space Plane (OSP), while our industry partners are developing the vehicle conceptual designs and operations concepts. Companies that have developed other vehicles have had an opportunity to compete for design and development of OSP. The entire program is conducted through full and open competition allowing an unlimited opportunity for industry. Our existing industry partners can choose to leverage their work on OSP with other "space plane" efforts.

Questions submitted Representative Rob Bishop

Q1. Can NASA supplant the Russian Progress capability by developing the autonomous rendezvous and docking capability necessary to deliver cargo to the Space Station using ELVs?

If ELVs are used to take cargo to the Space Station, what shuttle derived systems or unique equipment will be utilized?

A1. The Integrated Space Transportation Plan (ISTP) provides the basis for NASA's planning with regard to launch vehicles and capabilities. Currently, the ISTP does not include the use of U.S. ELV-launched vehicles to transport cargo to the ISS. NASA has funded studies to private companies to develop cargo vehicle concepts for rendezvous and docking with the Space Station. In addition, the technology required to enable automated cargo capability, including both resupply and return to Earth, is planned to be demonstrated by DART (Demonstrator of Autonomous Rendezvous Technology) as part of the Orbital Space Plane (OSP) program. Under the direction of NASA's Space Architect, NASA has opened the widest possible trade space to consider alternatives for future cargo transport to the ISS by both national and international service providers.

The Russian Progress has been a very dependable vehicle for resupply and reboost of the ISS; Rosaviakosmos remains committed to continuing to fulfill their ISS Program obligations. Additionally, both our European and Japanese Partners have been developing vehicles that are planned to be able to launch on ELVs and provide autonomous rendezvous and docking to the ISS. The European Ariane Automated Transfer Vehicle (ATV) is planned to be available starting in the late FY 2004 timeframe and the Japanese H–II Transfer Vehicle (HTV) is planned to be available starting in the early FY 2008 timeframe.

In the wake of the *Columbia* accident, NASA is reevaluating our approach to space access. NASA's Space Architect is leading a review of the ISTP to determine if revisions should be made. The effort includes re-evaluating the need for assured cargo access to ISS for resupply and return. We cannot at this point predict what Shuttle-derived systems or equipment might be utilized should U.S. ELV-launched vehicles be used for this purpose.

Q2. It appears that the Integrated Space Transportation Plan is not a long-term plan, but rather a short-term plan to satisfy the people and cargo requirements for the Space Station. Does NASA have a more global long-term strategic plan for future space transportation?

A2. Objective 8.2 of NASA's Strategic Plan calls for the Agency to "Improve the safety, affordability, and reliability of future space transportation systems." To implement this objective, we have developed the Integrated Space Transportation Plan (ISTP), which is the Agency's long-term investment strategy for space transportation systems. The ISTP provides a framework for the important near-term decisions and developments, such as upgrading the Shuttle and developing the Orbital Space Plane. The longer term portion of ISTP, the Next Generation Launch Technology Program, will invest in key technologies that will be the foundation for the development of future launch vehicles. In light of the *Columbia* accident, the current ISTP is now under evaluation and will be revised as necessary to ensure that our investments in space transportation remain consistent with the Agency's top level missions and objectives.

Q3a. NASA has been unsuccessful in developing any new launch technology or systems. Other than safety and performance upgrades, and the new Service Life Extension Program, what studies have been performed to expand the Shuttle's capability using an evolutionary approach?

A3a. NASA has recently undertaken a new study on the feasibility of sharing power between the International Space Station (ISS) and the Space Shuttle. If the feasibility of this concept is proven, it could enable longer stays at the ISS.

Q3b. What is required to develop the Extended Duration Orbiter or Long Duration Orbiter capability to permit on-orbit stays of 30 days? 60 days?

A3b. The Space Shuttle currently has the capability to stay on orbit for 16 days plus two additional contingency days with extended duration equipment. Unfortunately, the EDO pallet hardware was lost in the *Columbia* accident and we do not have spare equipment of that kind. However, two of the three remaining Orbiters have the necessary equipment interfaces to support extended duration.

NASA has completed a preliminary study to assess the feasibility of extending the Shuttle's on-orbit time to both 30 and 60 days. The study revealed that the extended stay time is possible but requires extensive hardware and software development. Depending on the recommendations from the *Columbia* Accident Investigation Board and the requirements for extended time on-orbit, further definition studies would be required before such a program could be undertaken.

Questions submitted by Representative Ralph M. Hall

Q1. NASA's International Space Station (ISS) independent cost reviews assume that the ISS operational lifetime ends in 2016. The updated Integrated Space Transportation Plan indicates that a decision could be made on whether to extend the Space Station operations beyond that date. When would NASA make that decision, and what are the criteria that would be used?

A1. Since ISS elements are deployed over a multi-year period, the U.S. Lab launch is frequently cited as the date of ISS deployment, which leads to the referenced lifespan to 2016. The key criterion that will be used to decide if ISS operations should continue is the continuing value of scientific research performed on the ISS. NASA and its International Partners will make the decision on whether to extend the life of the International Space Station (ISS) several years in advance of the end of the certification period, which is 15 years after being deployed into orbit.

Q2a. With respect to Orbital Space Plane (OSP) operations:

How many times a year do you estimate that the OSP will travel to the Space Station on average? What is the maximum and minimum number of times?

A2a. We are currently refining the OSP to ISS mission model. With the assumption that a single vehicle can handle a crew of at least 4 persons (per the Level I requirements) and a nominal crew rotation of 4–6 months (per the Level I requirements), the minimum number of flights would be 2–3 per year. However, until the final vehicle and operational concepts have been selected as well as the final ISS crew size, flight rates will remain an undefined variable in the analysis process.

Q2b. How many times do you estimate that the Orbital Space Plane would fly to the Space Station over the Space Station's lifetime?

A2b. As stated above, until decisions are made on crew size, crew rotation, cargo delivery, ISS lifetime, and OSP design and operational concepts, the flight rates are undefined. If you assume initial operational capability by 2010 for the CRV, rotations of 2 per year, and ISS lifetime of 2016, one could estimate a minimum of 14 flights.

Q2c. How many permanent crew will be on the Space Station when the OSP begins its crew return function in 2010? When it begins its crew transfer function in 2012?

A2c. The ISS Partnership has evaluated their research requirements for the ISS and determined, based on current estimates of crew time and performance, that a permanent crew of greater than 3 is needed to fulfill those requirements. The current crew size of two is constrained by consumables. Until the Shuttle returns to flight, the crew will remain at two. Following the Shuttle's return to flight, the crew will return to three and will be constrained by the availability of emergency crew return and the life-support capabilities of the ISS core configuration. With additional crew return capability and enhancements to the ISS, the permanent crew could potentially be expanded beyond three. The Partnership is discussing options for the provision of these enhancements. At the December 2002 ISS Heads of Agency meeting in Tokyo, the ISS Partnership agreed to pursue a configuration option that, would increase the size of the ISS crew beyond three beginning in 2006–2007 timeframe to meet ISS utilization and resource requirements.

The number of permanent crew on the ISS after OSP becomes available also will be dependant on research requirements and the crew capacity of the OSP. For instance, if the OSP can provide emergency return for a crew of four, the ISS crew could potentially be expanded to seven (three accommodated in the Soyuz and four on the OSP). The same formula will apply for the OSP crew transfer vehicle.

Q2d. By what date will you commit to a Space Station permanent crew size?

A2d. At the December 2002 ISS Heads of Agency meeting in Tokyo, the ISS Partnership agreed to pursue a configuration option that, would increase the size of the ISS crew beyond three beginning in 2006–2007 timeframe to meet ISS utilization and resource requirements. The Partnership further agreed on a process for selecting a final ISS configuration by December 2003. The *Columbia* accident and the grounding of the Shuttle fleet have impacted this timeline. A meeting of the ISS Heads of Agency will be held in late July 2003 to continue these discussions.

Q2e. How many vehicles will be in the OSP fleet and what is the basis of that number?

A2e. It has not been determined at this time. The preliminary data to support a response to this question will be available after the SRR this fall.

Q2f. For any items that you are unable to answer, please provide the date by which you expect to have the requested information.

A2f. Not applicable.

Q3. Will NASA disassemble and de-orbit the Space Station at the end of its operational life? If not, what do you propose to do? If so, will the Orbital Space Plane be capable of that task, or would the Space Shuttle be required?

A3. At the end of its operational lifetime, the ISS must be decommissioned and disposed of in accordance with U.S. laws and international treaties. The ISS decommissioning plan is phased over several months and would begin with the suspension of altitude maintenance six months before the final decommissioning phase. Final lowering maneuvers over a series of three orbits will complete the de-orbit, enabling the ISS to fall harmlessly into a remote region of the South Pacific Ocean. Neither the Space Shuttle nor the Orbital Space Plane will be used in the decommissioning of the ISS.

Q4. NASA's June 13, 2002 letter to me announcing shutdown of the X–38/CRV program stated that "NASA has concluded that pursuit of a multipurpose vehicle, which could include both crew transport and crew return capabilities is a more optimal use of NASA's resources than pursuit of a single-purpose vehicle, such as the X–38 project." However that statement is contradicted by the February 18, 2003 "Orbital Space Plane Level I Requirements Program Interpretation Document that states [page 4]: "The CRV and CTV vehicles) could be. . .completely different designs." Please explain.

A4. The OSP Level I requirements were specifically worded to allow the industry partners the flexibility to consider numerous options for the OSP. From a cost-competitive perspective, pursuing different designs for CRV and CTV would certainly be a challenge, but NASA will not preclude such an option. It is vital that the Level I requirements, which include both CRV and CTV, are considered as a single requirement. The OSP must be capable of addressing all 10 of these requirements.

Questions submitted by Representative Bart Gordon

Q1. In your testimony you stated that a decision on whether to proceed with the full-scale development of an Orbital Space Plane would be made in 2004.

Q1a. What are the criteria that will be used to make that decision? Please provide them for the record.

Q1b. How were the criteria derived? Were they externally reviewed? If so, by what entity?

Q1c. If the criteria are not yet available, by what date will they be?

A1a,b,c. The final evaluation criteria have not been developed. The process will include a detailed engineering review of the each of the industry partners' conceptual designs and operational concepts and their respective abilities to meet the OSP Level I requirements. The review will include an assessment of technical feasibility, level of technology readiness, business case closure and the trade studies conducted to develop their final plans. In addition to the evaluation of the inputs from the industry partners, the ultimate decision to proceed with a Full Scale Development will depend upon the priorities within the Agency and the funding available to meet the NASA missions and objectives. The criteria will be available prior to the RFP release, currently planned for early 2004.

Q2a. In your written testimony, you state that the updated Integrated Space Transportation Plan (ISTP) "defers development of a next-generation of launch vehicles until long-term goals are adopted that can justify the expense." You also state that: "Given the uncertainty of the market and the higher cost of RLV [Reusable Launch Vehicle] development, NASA concluded that the economic case for a new RLV was in doubt for the foreseeable future." However, the FY 2004 budget request projects spending almost $3 billion from FY 2003 through FY 2008 on the Next Generation Launch Technology (NGLT) program.

What is the specific rationale for the proposed $3 billion expenditure?

A2a. NASA's Next Generation Launch Technology (NGLT) program is NASA's only investment in the development of advanced technologies for space-launch capabilities beyond the Space Shuttle and existing expendable boosters. The current ISTP calls for decisions in FY 2004 and FY 2009 on whether or not to begin focused efforts leading to specific vehicles/systems concepts that could be operational approximately a decade after any such decision. Significant technological advancements are required to assure major, concurrent increases in safety, reliability, affordability and responsiveness in missions important to the U.S. The right investments in NGLT will help to meet national needs for future space exploration, national security, and civil/commercial markets in space.

Q2b. What criteria have been used to justify the $3 billion spending plan, and what will be the specific products/accomplishments that will result from that expenditure?

A2b. The general criteria for justifying the FY 2005 to FY 2008 investment is derived in part from the more general missions and objectives of NASA and the Aerospace Technology Enterprise—in terms of national needs for future space exploration, national security, and civil/commercial markets in space. Specifically, Objective 8.2 of NASA's Strategic Plan calls for the Agency to "Improve the safety, affordability, and reliability of future space transportation systems." Both perspective and data for justification are also available from the final report of the President's Commission on the Future of the U.S. Aerospace industry: NGLT provides implementation for many of the Commission's key recommendations (such as reversing the decline in U.S. share of the commercial space-launch market, now down to 19 percent from 75 percent in the 1970's). International competition, industry workforce/expertise and prudence in nation-investment planning are also considered in the report.

The NGLT Program has developed more detailed criteria for investments by applying systems analyses to a balanced set of missions and associated mission requirements. The list of NGLT projects and scheduled milestones covers the most critical technologies required for the full-scale development of a future space transportation system. NGLT includes technologies for both rocket- and air-breathing propulsion, for reusable and expendable airframes, and for ground-based and flight demonstrators.

Planned accomplishments of NGLT projects will include a number of firsts:

- Rocket Engine Prototype: demonstration of a highly reliable hydrocarbon-fueled rocket-booster engine (1+ million-pound thrust), the first in 40 years for the U.S.
- Auxiliary Propulsion: non-toxic propellants for on-orbit propulsion and maneuvering

- Vehicle Research and Technology: airframes capable of both containing cryogenic propellants and re-entering the Earth's atmosphere; durable, high-temperature thermal-protection systems; and intelligent, autonomous, "all-electric" launch systems
- Propulsion Research & Technology: Long-life, lightweight high-temperature materials, seals and components
- X–43A & C: first controlled, atmospheric flights of vehicles powered by an air-breathing engine with no rotating parts, e.g., by scramjet from Mach 5 to 7 and Mach 10
- Turbine-Based Combined Cycle (engine): lightweight, long-life jet engines capable of flight at up to Mach 4 (4 times the speed of sound)
- Rocket-Based Combined cycle (engine): engines capable of both air breathing (scramjet) and rocket propulsion within one system.

Q3. Please provide the planned dates of the following Orbital Space Plane milestones.

A3. The dates below reflect the current OSP Program Plan. These may change as the formulation studies proceed.

a. System Requirements Review
 10/27–12/9/03

b. System Design Review
 4/20–6/16/04

c. Critical Design Review
 1/23–3/7/07

d. Decision on Full Scale Development
 9/17/04

e. Completion of Level II and Level III requirements
 The Government-developed Level II requirements will be finalized in conjunction with the upcoming SRR this fall. The Level III requirements will be finalized by the SDR. (4/20–6/16/04)

f. Request for Proposals
 2/17/04

g. Contract Award(s)
 12/2/04

h. Completion of independent cost estimates of acquisition cost and of life cycle cost
 Activities are underway with multiple interim deliverables concluding with final product deliverables around mid September 2004.

i. Flight tests of OSP Crew Return Vehicle
 Mid to late FY 2008 timeframe

j. Flight tests of OSP Crew Transfer Vehicle
 Mid to late FY 2010 timeframe

Q4. Administrator O'Keefe told Rep. Hall on September 30th that, "based on an independent assessment of X–38 CRV project conducted in 1999, an X–38 CRV program would cost approximately $3 billion depending on the approach used in DDT&E and production." When the study actually said the CRV fleet costs would be $2.45 billion if NASA followed a business as usual approach and only $1.26 billion if NASA followed the approach advocated by the X–38 project officer, and which was acknowledged as such by the NASA cost analysis division. Please explain this discrepancy?

A4. The figures included in the 1999 Independent Program Assessment Office (IPAO) report included the $2.5 billion and $1.3 billion estimates. However, the IPAO estimates assumed funding for the X–38/CRV in the years FY 1999–2005. At the time of the Administrator's letter to the Committee in late FY 2002, it was obvious that the funding estimates being provided should reflect "FY 2003 and outyear" dollars. When the $2.5 billion estimate for "business as usual" was converted to "FY 2003 and outyear" dollars, the estimate was converted to $2.908 billion, which is consistent with the "approximately $3 billion" figure used in the Administrator's letter. The figure used in the letter focused on the higher end of the range (i.e., the $2.5 billion, which converts to $2.9 billion) because many observers of the X–38/CRV program had doubts that a "rapid prototype approach" was suitable for a human-rated vehicle that would be required to service the International Space Station, and that it would be prudent to use the more conservative cost number.

The IPAO report does quote $2.5 billion for a "business as usual approach" to X–38/CRV, but when this value is converted to the budget years that correspond to the Administrator's letter, the $2.5 billion estimate inflates to $2.9 billion (or rounded to $3 billion). Thus, the statements relative to the IPAO estimate are accurate, as are the estimates used in the Administrator's letter of September 30, 2002—the estimates are simply using different "year dollars."

Q5. What do you estimate is the marginal cost of an OSP flight, including the procurement of the ELV?

A5. Cost estimation for the Orbital Space Plane (OSP) is in progress. NASA is committed to providing responsible, credible cost and budget estimates prior to committing to new development programs. We will be following NASA policy guidelines of using the formulation phase of the OSP Program, to be completed by the end of FY 2004, to establish cost and schedule commitments for the implementation phase. At that point, the requirements and conceptual design will be sufficiently understood to ensure a responsible and credible development cost commitment is made. As part of the OSP system design process, each competing architecture contractor is providing life cycle cost estimates as a major deliverable. Government cost experts are developing cost estimates in parallel, utilizing legacy cost data from prior programs along with improved and validated cost analysis and estimating tools. A Cost Credibility External Review Team, reporting to the OSP Program Manager, is being established to provide expert assistance in ensuring credible cost estimation. In addition, an independent cost validation will be performed utilizing a Cost Analysis Requirements Document, as used by the Department of Defense and on the International Space Station Program. These various cost estimates will be studied and understood prior to the Full Scale Development decision. In addition, we are ensuring fiscal accountability on all ongoing OSP Program activities by using a proven Earned Value Management system to track actual cost and schedule performance as compared to plans.

Questions submitted by Representative Nick Lampson

Q1. Mr. Gregory, under the international agreements governing the International Space Station, the United States has a commitment to provide a crew rescue capability by 2006. As you know, the Russian commitment to provide Soyuz crew return vehicles for non-Russian crew members expires in 2006.

Q1a. When the Administration canceled the existing Crew Return Vehicle (CRV) program in early 2001, what was its alternative plan for fulfilling the 2006 CRV commitment? Did it have an alternative plan?

Q1b. The Orbital Space Plane will not be available for Space Station crew return until 2010 under your plan. How do you intend to meet the U.S. commitment to provide crew return over the years 2006 to 2010?

A1a,b. As currently envisioned, NASA's Orbital Space Plane (OSP) will provide crew return capabilities and crew transfer capability in the in the 2010 time frame. As part of the Agency's continuing ISTP reassessment, we are reviewing the timeframe in which OSP can be made available. The ISS Partnership is addressing the requirement for accommodation of crew rescue capabilities after 2006 as part of the ISS Program Action Plan, established at the Tokyo 2002 Heads of Agency meeting. At this meeting, the Partners agreed that crew rescue for the increased crew would initially be provided by additional Soyuz crew rescue vehicles and eventually by both Soyuz and the Orbital Space Plane. The specific Soyuz vehicle requirements and funding arrangements will be developed as part of the process of resolving ISS configuration issues. All of the ISS Partners recognize that any solution related to ISS crew rescue must be consistent with U.S. law.

Q1c. Since your written testimony indicates that accelerating the Orbital Space Plane might advance its availability to serve as a CRV by only 6 months to a year, the Soyuz is the only other means of providing a CRV capability for the Space Station between 2006 and at least 2009. Does NASA plan to acquire Soyuz services to meet its CRV commitment over this time period? If so, how?

A1c. At the December 2002 ISS Heads of Agency meeting in Tokyo, the ISS Partnership agreed to pursue a configuration option that, if followed, would increase the size of the ISS crew beyond three beginning in 2006–2007 timeframe to meet the ISS utilization and resource requirements that had been revalidated in 2002. At this meeting, the Partners agreed that crew rescue for the increased crew would initially be provided by additional Soyuz crew rescue vehicles and eventually by both Soyuz and the Orbital Space Plane. The specific Soyuz vehicle requirements and funding arrangements will be developed as part of the process of resolving ISS configuration issues. All of the ISS Partners recognize that the solution must be consistent with U.S. law regarding funding for NASA's human space flight activities. The Partnership had planned to complete this process by December 2003, but the loss of Space Shuttle *Columbia* in February 2003, interrupted the multilateral work on these ISS configuration issues, including those related to the provision of crew return capability beyond a crew of three. A meeting of the ISS Heads of Agency will be held in late July 2003 to discuss how this process can be reinitiated based on the current plans for the return to flight of the Space Shuttle.

Q1d. Any arrangement that would have the other International Partners pick up the responsibility for crew return from 2006 to 2010 in exchange for some offset of their own operating cost obligations would appear to be prohibited by the Iran Nonproliferation Act*—do you agree? If so, what will you do?*

A1d. Until there is a proposed Partnership plan on how to address accommodation of crew rescue capabilities using additional Soyuz in the 2006–2010 timeframe, it is not possible to comment on the implications of the *Iran Nonproliferation Act of 2000* on such a plan.

Q1e. Mr. Gregory, under the international agreements governing the International Space Station, the United States has a commitment to provide a crew rescue capability by 2006. As you know, the Russian commitment to provide Soyuz crew return vehicles for non-Russian crew members expires in 2006. Has Russia agreed to provide Soyuz CRVs for non-Russian astronauts after 2006 without seeking any compensation or offsets?

A1e. No. The ISS Partnership is addressing the requirements for accommodation of crew rescue capabilities after 2006 as part of the ISS Program Action Plan, established at the Tokyo 2002 Heads of Agency meeting. All of the ISS Partners recognize that any solution related to ISS crew rescue must be consistent with U.S. law.

Q1f. Have any of the other International Partners agreed to provide Soyuz CRVs for non-Russian astronauts after 2006 without seeking compensation or offsets? If so, which one(s)?

A1f. No.

Q2. In your written testimony, you describe at length the process that led to the adoption of the Integrated Space Transportation Plan. Was this plan reviewed by independent external panel(s)? If so, by whom, and when?

A2. Yes, it was reviewed by the Aerospace Technology Advisory Committee in February 2003.

Q3. Please provide the cost assessments and documentation supporting the cancellation of the X–38 CRV project?

A3. NASA provided the cost assessment and documentation supporting the cancellation of the X–38 CRV project to House Space and Aeronautics Committee staff with formal notification to Congressmen Hall and Gordon by letter dated January 15, 2003. A copy of the letters and supporting documentation is provided herewith.

[NOTE: See a copy of the letters referred to above and Request for Cost Information on X–38/CRV and SLI Cost Estimates in Appendix 2: Additional Material for the Record.]

Questions submitted by Representative Anthony D. Weiner

Q1a. Please clarify the relationship of the Orbital Space Plane program to Department of Defense or Intelligence requirements. Specifically, is NASA developing the Orbital Space Plane in support of DOD or Intelligence Agency missions?

A1a. No. The OSP Level 1 requirements were developed for the NASA-specific mission of providing crew and limited cargo to the ISS only.

Q1b. Has the Administration tasked NASA to develop the Orbital Space Plane for DOD or the Intelligence Agencies?

A1b. No.

Q1c. Have DOD or the Intelligence Agencies levied any requirements on the Orbital Space Plane program? If so, what are they?

A1c. No.

Q1d. Are DOD or the Intelligence agencies contributing any money to the Orbital Space Plane program?

A1d. No.

Q2a. A chart released by NASA as part of the Space Shuttle Service Life Extension Program conference in March 2003 said that the Orbital Space Plane would serve NASA and DOD missions.

If that is so, what DOD missions will be served by the Orbital Space Plane?

A2a. The OSP Level 1 requirements were developed for the NASA-specific mission of providing crew and cargo to the ISS only.

Q2b. What discussions have you had with DOD about contributing part of the funding for the Orbital Space Plane program?

A2b. NASA has not had discussions with DOD about DOD contributing funding for development of the OSP. OSP Level 1 requirements have been developed to meet NASA-specific requirements. However, NASA and DOD have agreed to share data on Agency programs that are mutually beneficial. For example, there is mutual interest and cooperation in the development of autonomous rendezvous and proximity operations technology. NASA is funding the Demonstration of Autonomous Rendezvous Technology (DART) technology demonstrator through the OSP program. DART will demonstrate an Advanced Video Guidance Sensor that will also be used by DARPA's Orbital Express Program. NASA is interested in data from the Orbital Express program, as well as the Air Force Research Lab XSS–11 program, which is providing complementary autonomous rendezvous technology development and may be relevant to the OSP Program.

Q2c. What funding has DOD agreed to provide?

A2c. None.

Q3a. Regarding potential DOD–NASA cooperation on space plane technology, Administrator O'Keefe has been quoted as having said on April 17, 2003 that:

"I'm very optimistic that more of these technologies, if not certainly the final objective of any one of these craft, can be done in much greater concert. And we're moving in that direction and I think you'll see greater evidence of that in the coming budget effort that we're putting together now."

Do you plan to establish a joint DOD–NASA Orbital Space Plane program?

A3a. At this time no formal joint program has been discussed or planned.

Q3b. If not, what is the Administrator talking about?

A3b. The Administrator was referring to the National Aerospace Initiative (NAI), which is a partnership being established between NASA and DOD. The Next Generation Launch Technology (NGLT) Program is heavily involved in this partnership, as its scope encompasses the planned goals of the NAI.

Q4a. You state that the Orbital Space Plane has a requirement to be safer that the Space Shuttle and the Russian Soyuz.

What does that statement mean?

A4a. That statement was taken from the OSP Level 1 Requirements, which were established to provide the top-level guidelines the program, must meet to be successful. The language of the Level 1 requirements below are meant to convey the Agency's intention to improve crew safety with the new system:

"The risk of loss of crew shall be, with high confidence, lower than the Soyuz for the rescue mission," and "The risk of loss of crew shall be, with high confidence, lower than the Space Shuttle for the transport mission."

Further definition of how NASA will meet such a requirement will be developed with the Level 2 requirements, which we expect to be finalized this fall.

Q4b. What is the current level of catastrophic accident risk for the Shuttle? What is the basis of that number?

A4b. The predicted risk of catastrophic Shuttle failure during a mission is 1 in 265. This risk was based on the 2000 update to the 1998 Quantitative Risk Assessment System (QRAS) model. The Shuttle program is completing a new probabilistic risk analysis for the Space Shuttle due out in the fall of this year.

Q4c. What is the current level of catastrophic accident risk for the Soyuz? What is the basis of that number?

A4c. The Soyuz refers to the launch vehicle and to the crewed spacecraft. Since 1980, when the current version of the Soyuz launch vehicle was put into service, it has flown 577 times, with 562 successful missions. The Soyuz spacecraft first launched on April 23, 1967; there have been two catastrophic failures out of approximately 89 missions.

Questions submitted by staff of House Committee on Science

Q1. What are the underlying assumptions, e.g., budget, technology and schedule, used to develop the new ISTP?

A1. In light of the *Columbia* accident, the current ISTP is under evaluation and will be revised, if necessary, to ensure that our investments in space transportation remain consistent with the Agency's top-level missions and objectives. NASA awaits the *Columbia* Accident Investigation Board (CAIB) recommendations that will serve as the foundation for any changes to the ISTP.

Q2. When will the new plan be ready?

A2. Any revision to the ISTP will be not be ready before the CAIB final report is released. Some time will be needed after the release to respond to recommendations and incorporate them, if necessary, into the ISTP.

Q3. Will the budget amendment reflect the new ISTP?

A3. No decision has been made on a budget amendment. If the ISTP is revised following release of the CAIB report, NASA will evaluate any associated resource implications.

Q4. What options other than the Shuttle is NASA considering for providing cargo transport to the Station?

A4. NASA is considering several U.S. options for assuring cargo access to ISS in the event that the Shuttle is unable to deliver cargo. For near-term contingencies, NASA is considering the concepts proposed by the four Alternate Access contractors that might satisfy ISS upmass and downmass requirements. For the longer term, as part of the New Generation Launch Technology (NGLT) program, the ISTP has a decision point at the end of FY 2004 to determine whether NASA should begin a focused technology risk reduction program leading to a new launch vehicle.

Q5. Does NASA have specific plans and schedule milestones to develop the capabilities that would obviate the need for the Shuttle after the Station construction is complete?

A5. No.

Q6. What reviews have the External Program Assessment Team (EPAT)/External Requirements Assessment Team (ERAT) performed on the SLI and specifically on OSP? Please provide names of the members of these teams?

A6.

EPAT-Completed (October 2001–December 2002)

- NRA8–30 Requirements and Program Plan
- Level 1 Requirements for SLI
- Reported Results of 3 Prime Contractors for SLI at Interim Program Reviews against SLI 2nd Gen. RLV Requirements
- 2nd Gen. Systems Requirement Review–Independent Assessment
- 2nd Gen. Integrated Architecture Review Board Participation and Assessment
- Independent business case option for SLI 2nd Gen. RLV
- Assessment of 120 Day Study Results of NASA–Air Force RLV Options
- Assessment of Human Rating Requirements for 2nd Gen. RLV.

EPAT January–June 2003

- Sub-Team Participation in X–37 Management Review (complete)
- Sub-Team Participation in Apollo Command Module Study for OSP (complete)
- Level 2 Requirements for OSP (Report in preparation)

- Assessment of external concepts (to OSP) for value added in OSP (Report in preparation)
- Assessment of cost, schedule, performance balance for OSP (initiated 6/03)

EPAT/ERAT TEAM MEMBERS:

Angelo Guastaferro
Tom J. Gregory
Frederick H. Hauck
J. Wayne Littles
Chester L.Whitehair
Kenneth J. Szalai (Chair)

Q7. What additional independent and non-advocate reviews are planned for OSP and when are they scheduled?

A7. The President's FY 2004 budget request assumed a Non-Advocate Review (NAR) and an Independent Cost Review (ICR) in mid 2004. Although a specific date is not finalized for completion of the reviews, the accelerated OSP plan anticipates they will begin in early 2004.

Q8. Has NASA established the OSP Cost Credibility Team? Who are the members of the OSP Cost Credibility Team? What analysis has been done thus far?

A8. Yes, NASA has established the OSP Cost Credibility Team. The team includes personnel from Marshall Space Fight Center, Johnson Space Flight Center, Kennedy Space Center, and representatives from industry. Thus far, the Cost Credibility Team has completed the following tasks:

- Benchmarking efforts which include surveying industry to determine best practices
- An internal assessment of the NAFCOM (NASA/Air Force Model) costing tool
- Asked contractors to evaluate NAFCOM.

The Team will continue its work to address issues such as cost estimate validation, consistency of funding profile to schedule, and cost risk identification and mitigation.

Q9. When will the Cost Analysis Requirements Document (CARD) be completed?

A9. The President's FY 2004 Budget Request assumed a CARD prior to the contract award late 2004. Although a specific date is not finalized at this time, the accelerated OSP plan anticipates a CARD will be completed by late summer 2004.

Q10. Please provide the latest OSP schedule.

A10. Following is the schedule assumed by the FY 2004 President's Budget Submission:

- Late 2003: System Requirements Review completed
- Mid 2004: System Design Review completed
- Early 2004: Request for Proposals issued
- Late 2004: Contract Award
- Spring 2007: Critical Design Review
- 2010: Crew Return Vehicle Initial Operating Capability (IOC)
- 2012: Crew Transport Vehicle Initial Operating Capability (IOC)

Following is the schedule anticipated with acceleration of the OSPP:

- August 2003: JOFOC (Justification for other than Full and Open Competition) approved
- September 2003: Level Two Requirements completed
- September–October 2003: Request for Proposal (RFP) developed by joint NASA/Industry Teams
- November 2003: Request for Proposal (RFP) issued to contractor teams
- January 2004: System Design Review (SDR) completed
- Early 2004: Non-Advocate Review (NAR) and Independent Cost Review (ICR)
- Spring 2004: Interim Design Review
- Spring 2004: Contractor proposals reviewed by NASA
- Late Summer 2004: Contract award

- 2005: Critical Design Review (CDR) completed
- 2005: Start production of two operational units for atmospheric/orbital testing and initial Crew Return Vehicles
- 2008 or sooner: Crew Return Vehicle IOC
- 2010: Crew Transport Vehicle IOC

Q11. What is the period of performance of the three existing OSP study contracts, e.g., Boeing, Lockheed-Martin, and Orbital/Northrop-Grumman?

A11. The initial OSP study contracts were awarded in May 2001, modified in April 2003, and continue through July 2004. Consistent with the acceleration plan, a letter RFP will be issued by NASA to shorten the schedule for the studies while maintaining the existing scope.

Q12. At the end of this phase what are the contractor's deliverables?

A12. The April 2003 contract modification includes work to develop system specifications, including systems analysis, trade studies and concept feasibility in preparation for the OSP Systems Requirements Review. The SRR was scheduled under the President's FY 2004 Budget Submission for late 2003. The accelerated plan anticipates September 2003 for completion of the SRR. Once the SRR is complete, the contractors will begin work on the next phase, which includes trade studies, development of a conceptual design that meets Level Two requirements, and supporting analysis leading to NASA's Systems Design Review. The SDR was scheduled for completion mid 2004 under the President's Budget Submission and is scheduled for completion January 2004 under the accelerated plan.

Q13. Does NASA plan to continue with the three contractors after the SRR?

A13. Yes. The three contractors will continue on until the Systems Design Review, scheduled for mid 2004 under the President's Budget Submission, and January 2004, under the accelerated plan.

Q14. When does NASA plan to release the RFP?

A14. The RFP was scheduled for early 2004 under the President's Budget Submission and November 2003, under the accelerated plan.

Q15. When will NASA have a full life cycle cost estimate?

A15. A life cycle cost estimate for OSP was scheduled prior to Fall 2004 under the President's Budget Submission and is scheduled for late summer 2004, under the accelerated plan.

Q16. The Level One Program Interpretation Document (PID) says the OSP program will use the 2020 Concept of Operations and ISS Traffic/Mission Model as the basis for life cycle cost calculations. Please provide these.

A16. Both of these efforts are in progress; results will be provided upon completion. Completion of these activities is scheduled to occur in Fall 2004 under the President's Budget Submission and late summer 2004, under the accelerated plan.

Q17. What analysis has NASA performed to arrive at the requirement to "provide ongoing medical treatment to the crew until arrival at definitive medical care within 24 hours?" Why is 24 hours the appropriate time constraint? Does the Soyuz capsule meet this requirement? Would NASA revise this requirement if it becomes a major cost or schedule driver?

A17. Several risk studies have been performed over the years using analog populations, space flight experience and ground-based data from flying populations. One of the risk studies was a Probabilistic Risk Assessment by Futron. These studies led to consistent risk determinations. A crew member has the likelihood of a serious medical event that will need treatment and possible evacuation to a Definitive Medical Care Facility (DMCF) of 0.06 incidents per person-year. The likelihood of occurrence of a critical event that will require evacuation is 0.01 per person-year.

A 1989 survival study of military and civilian aircraft mishaps indicated the first 12 to 24 hours after an incident are the most critical for the recovery of survivors. Injured survivors have a decreased life expectancy of up to 80 percent after the first 24 hours. A U.S. Air Force study noted the need to treat type II decompression sickness (DCS) cases (e.g., neurological injuries) within 12 hours for optimum treatment.

Twenty-four hours is the elapsed time from making a decision to bringing an injured or ill crew member to a terrestrial Definitive Medical Care Facility (DMCF). The 24-hour requirement is a "worst case" scenario with transport of 12 hours or less highly desirable in certain critical medical care scenarios. The transport vehicle only needs to provide medical care for the transport portion of this 24-hour window.

Yes, Soyuz landing operations meet the requirement to "provide ongoing medical treatment to the crew until arrival at definitive medical care within 24 hours."

If the definitive medical care requirement (Level One) is determined to be a major cost or schedule impediment, it will be reviewed for change at the Agency level.

Q18. The expert witnesses at the OSP hearing unanimously called for the inclusion of a crew escape system during ascent. Does NASA believe that a crew escape system is necessary to meet the PID requirement of 1/400 risk of crew loss?

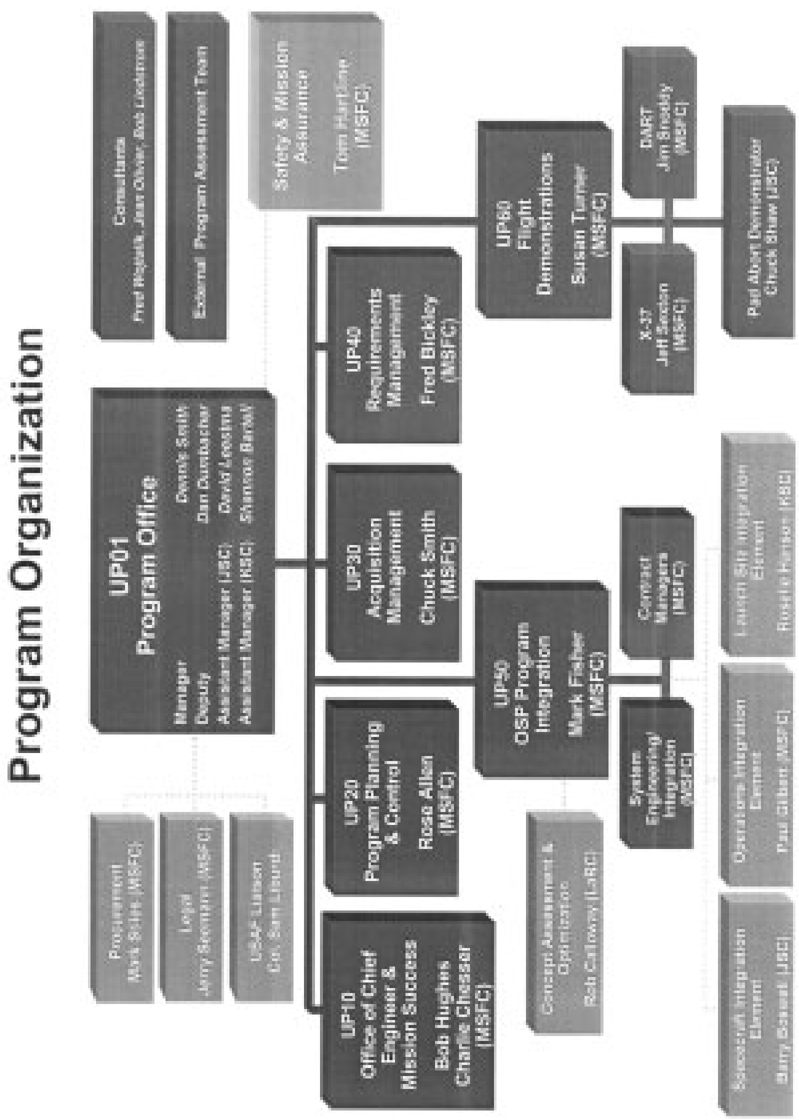
A18. NASA has not yet received detailed proposals from the OSPP contractors that specify how the contractors would meet crew escape requirements.

Q19. How will NASA determine the system reliability of the ELV?

A19. NASA will use both historical data and predictive models (e.g., Probability Risk Assessments) to determine the reliability of the ELV.

Q20. Please provide the organization charts for the OSP program including those located at the field centers.

A20. See organization chart for the OSP program.



Q21. What plans beyond the Demonstration of Autonomous Rendezvous Technology (DART), if any, does NASA have to develop an operational autonomous rendezvous and docking capability?

A21. Outside of DART, NASA has no specific plans to develop an autonomous rendezvous and docking capability. In light of the *Columbia* accident, NASA will consider a variety of ISS cargo capability options, including the autonomous docking of Shuttle.

Q22. According to NASA's schedule the Pad Abort Demonstrator (PAD) tests are performed after the full scale development decision, will the PAD results be available in time to incorporate a crew escape system into the OSP?

A22. Yes, PAD ground demonstrations are scheduled to begin after OSPP FSD decision but prior to OSPP Preliminary Design Review and will be completed prior to Critical Design Review. While the OSPP contractor(s) are not required to use the data from the PAD demonstrator in their designs, the data will be made available to them in time to affect their designs.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Jerry Grey, Director of Aerospace and Science Policy, American Institute of Aeronautics and Astronautics

Questions submitted by Chairman Dana Rohrabacher

Q1a. Should we move forward with large-scale manned spacecraft development efforts in the absence of a broader view or even a specific destination like the Moon or Mars?

A1a. No.

Q1b. If so, please explain how we should move forward.

A1b. What is needed first is a plan, in some detail, for future manned missions beyond low Earth orbit. NASA is currently constrained from conducting any such planning until the space station has been completed. But the original purpose of the space station—and still its only truly unique function—is to learn and demonstrate the operations needed for just such missions. Hence advanced manned-mission planning, at acceptably low budget levels, should be pursued. The guidelines for conducting such planning should include identifying and specifying first-level transportation requirements. Once these requirements have been defined, consideration of future manned spacecraft would be appropriate, including development budget estimates. Decisions on proceeding with large-scale manned spacecraft development could then be made on a sound basis.

Q2a. Does NASA have the management and technical depth to effectively assess the results of [OSP] contractor studies?

Q2b. What recommendations do you have to strengthen NASA's capability to successfully manage the OSP program?

A2a,b. NASA does have strong management and technical depth to assess the results of contractor studies, especially at the Marshall and Johnson centers. These abilities could, however, be improved by creating a new NASA Advisory Council committee, composed of senior spacecraft- and transportation-system engineering and management experts outside NASA and the OSP contractors, to conduct an ongoing review of NASA management practices and decisions on contractor work during the OSP development process. This would ensure the timely identification and correction of any inadequacies in NASA's management of contractor work.

Q3a. Can you please provide specific examples of [OSP] technologies which must be demonstrated?

A3a. The key technologies that should be demonstrated prior to initiating full-scale OSP development are the thermal protection system; an autonomous, fast-response flight control system; an integrated health management system, preferably embedded in an fault-tolerant vehicle architecture; a crew rescue system, autonomous rendezvous, and pad-abort. Although some of these are not "unproven" technologies, they have not been flown on an OSP-like configuration or mission profile.

Q3b. Do you think NASA's plan for technology demonstrations, more than $700 million, is the best use of funds for the OSP program?

A3b. Technology demonstrations, unlike technology development, are aimed primarily at mission assurance goals, rather than proving technology feasibility. In the environment following the *Columbia* loss, mission assurance is perhaps the key feature any new transportation system must have. I cannot argue for or against NASA's contention that they would cost $700 million, but they are certainly worth doing in a project whose ultimate cost is pegged at $9–$13 billion. A "drop-in friendly" design would help to ensure that promising new developments can be introduced without incurring additional costs or scheduling delays.

Q3c. Should all this funding be spent on vehicle development rather than technology demonstrations?

A3c. These technology demonstrations could perhaps be upgraded to culminate in a full-up demonstration flight test of the final OSP design, which would be the best possible mission assurance tool. However, this would entail higher risk than the planned pre-development technology verification effort.

Q4. What recommendations do you have to prevent OSP from becoming the latest failure [due to overambitious goals]?

A4. The best way to avoid an overambitious program is to design a system that draws heavily on existing, proven technologies and then verify their application in the new program by proven verification methods (e.g., use of "heritage" components, analysis, simulation, testing, and flight demonstration).

One key factor in ensuring program success within budget and schedule is to scrupulously avoid "requirements creep." That is, extra time and effort should be spent on design and technology verification, which is relatively cheap, to avoid the need for introducing additional or more stringent requirements during full-scale development.

Q5. What must be done and how long would it take to expand the Orbiters' capabilities to include autonomous [ISS] proximity operations and autonomous landing capability?

A5. These capabilities are encompassed by current Orbiter technology. Although some minor hardware modifications might be needed, the bulk of the effort needed would be in the software. This should not offer any major barriers; the Russian Soyuz and Progress spacecraft already have the software needed for ISS proximity operations, and their Buran has already demonstrated autonomous landing. Hence refitting the Orbiters for autonomous operations should be able to be accomplished by the time the fleet returns to flight. Flight demonstration of this capability should also be relatively risk-free, since the crew of the first flight can override the controls if it becomes necessary.

Q6a. What needs to be done and how long do you estimate it would take to develop the capability for converting the Shuttle's four-person flight deck to an escape capsule suitable for egress during all flight modes?

A6a. Converting the three orbiters as needed to make the flight deck a crew escape capsule would not be simple or cheap. It would involve major redesign and restructuring of the current Orbiter configuration, as well as verification. However, cockpit escape-capsule technology and processes have been in operational use for many years in military aircraft, so no new technology development would be required. If incorporated into the SLEP, I would estimate that it could be accomplished in a year for the order of $1 billion.

Q6b. Are there other crew escape scenarios that would substantially improve crew survivability?

A6b. There are certainly other alternative crew escape system design concepts that could be explored in a low-cost research program. For example, a low-cost concept based on the use of a small inflatable Rogallo-wing paraglider incorporating advanced materials that could be packaged in the payload bay and would survive the re-entry environment for the requisite short period was developed by Aerojet-General under contract to the USAF Materials Laboratory about 40 years ago. However, development, testing, and proper demonstration of any new design could take as long and cost as much as the Orbiter conversion.

Q6c. What independent evaluation method do you recommend for future NASA crew escape system proposals?

A6c. Again, the best verification method for any new system is a flight demonstration. Design, development, and verification of any proposed crew escape system could be overseen by the same committee of the NASA Advisory Council I suggested earlier, with the addition of one or more military personnel having experience in the development and operational use of aircraft cockpit ejection systems.

Q7a. Does NASA's Level-1 safety requirement for crew transport adequately address your concern for a launch abort system?

A7a. "Risk of loss of crew lower than the Shuttle" does not adequately define the crew rescue requirement. A system with a loss-of-crew risk better than 2 in 113 is not an acceptable design criterion for any crew escape system. Remember, the Shuttle currently has no real crew-escape capability, so using it as a criterion for an escape system does not make sense.

Q7b. Should a launch-abort system requirement be spelled out in the Level 1 requirements?

A7b. The launch abort capability should be part of the overall crew rescue requirement as spelled out in detail in a Level 2 document. The Level 1 requirement should define an acceptable loss-of-crew probability for all mission modes at some verifiable level well beyond that of the current Shuttle.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dale D. Myers, President, Dale Myers and Associates

Questions submitted by Chairman Dana Rohrabacher

Q1a. Should we move forward with a large scale manned spacecraft development efforts in the absence of a broader view or even a specific destination like the Moon or Mars?

A1a. Yes. I don't think we should stop development of the ISTP program.

Q1b. If so, please explain how we should move forward?

A1b. We should choose the moon, as an outpost, as our next destination, followed by Mars. In my view, that sequence of events is inherent as a follow-on to the ISTP program. First, a simple CRV and then a "Block 2" CTV, made up of an upgraded CRV and a small service module would be developed that is reusable or not. In parallel, ruggedize the Shuttle and expect fewer flights per year. Continue the technologies to develop a low cost transport to low earth orbit. Finally start a robotic outpost program to put living quarters on the moon. These quarters would become occupied after several years of reliable robotic operation, including local generation of oxygen and the recovery of water. After a decade or two of lunar operations, transport the same type of equipment to Mars, and set up a robotic outpost on Mars, followed later by human occupation.

Q1c. Would you please elaborate on the statement in your written testimony that "an eventual plan to return to the moon would favor choosing a capsule approach to a CRV/CTV"?

A1c. I'm a great believer in block changes in the evolving configuration of complex systems (like block I and block 2 in the Apollo Program). It is clear that winged vehicles don't make much sense in deep space operations. They are too complex, and their atmospheric parts like wings and landing gear are too heavy to carry to the moon and back. By starting with a capsule, and more specifically the Apollo CM capsule, (which I believe would be less expensive and with a shorter development time schedule than a winged vehicle) we start with an immense technology carry-over. Then, because a capsule is the way to go to the moon, the huge background of development and operational experience developed in the Apollo Program, and extended by the Command Module CRV/CTV, would carry over directly to the Lunar program, and then to Mars.

I must say that I'm not sure that the CM CTV would be lower in life cycle cost than a winged vehicle, because a capsule's low L/D may require more landing sites than the winged vehicle if the 24 hours to definitive medical help stays in the Level I requirements. Imaginative operations analysis is needed to compare the life cycle costs of both systems.

Q2a. Does NASA have the management and technical depth to effectively evaluate the results of the contractor studies?

A2a. I don't know. I haven't been involved with NASA for about 13 years, except for my 3 years on the Aeronautics Advisory Committee, and this recent study of using the Apollo Command Module for a CRV and/or CRV/CTV. In the little activity I have had, I found in NASA exceptional individual competence and a full commitment to doing things right. On the other hand, I didn't see the giants that we had in the Apollo Program, like Werner Von Braun, Bob Gilruth and George Low.

Q2b. From your experience with the Apollo and Space Shuttle programs, what recommendations do you have to strengthen NASA's capability to successfully manage the OSP program?

A2b. I would put the whole OSP program in one Center, with a small Headquarters oversight responsibility and with responsibility for Level 1 requirements. The Program Manager could "subcontract" the management of subsystem elements to other centers, but would not be required to do so. A very strong safety and reliability function would have to be developed, where anomalies like "O-rings" and "loose foam" type issues would be brought to the top headquarters function *as they happen.*

Q3a. Should NASA seek to develop a fully autonomous Shuttle Capability?

A3a. I can see cases where the Shuttle became a cargo system like the Russian Progress, and the CRV/CTV became the active transport of people and smaller cargo. Heavy lift capability to orbit is an important capability for NASA, whether or not the flight is autonomous.

Q3b. What technical barriers, if any, need to be addressed to develop a fully autonomous Shuttle?

A3b. I would be concerned about the enormous inertia of the Shuttle in proximity to the ISS in case anything went wrong. Man is an overriding safety device during docking. The conversion of the Shuttle to an entirely autonomous system is not a simple task, because it was designed for human interface. I would think that consideration might have to be given to autonomy for the CTV instead of the Shuttle because of its lower mass and that you could start from the beginning to do so.

Q4a. Does this requirement (the Level one requirement for "the loss of crew shall be, with high confidence, lower than the Space Shuttle for the transport mission") adequately address your concern for a launch abort system?

A4a. I think the Level 1 document needs to be a living, changing document as the Phase B program progresses. If NASA decides, out of the contractor's studies and their own, that a launch abort system is required, it should be incorporated in Level 1.

Q4b. Should a launch abort system requirement be spelled out in the Level 1 requirement?

A4b. Based on the answer to 4a above, the answer is "not now," but it is my opinion that it should be included soon.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Michael D. Griffin, President and Chief Operating Officer, IN-Q-TEL

Questions submitted by Chairman Dana Rohrabacher

Q1. Your written testimony states that NASA's plans "lack the required global framework, the desired broader view," and that this is "nowhere to be found in the ISTP proposal."

Should we move forward with large-scale manned spacecraft development efforts in the absence of a broader view, or even a specific destination like the Moon or Mars?

A1. It would certainly have been very desirable to have made decisions to this point on the Orbital Space Plane program in the context of, and relative to, an over-arching set of goals and objectives for the U.S. space program, including our next logical destinations (such as the Moon or Mars) and reasonable schedules for reaching them. As noted, this was one of the points that I made rather strongly in my testimony. NASA and the Administration should be encouraged to advocate such objectives, and the Congress should join in their definition and approval on behalf of the nation. Our progress in advancing the exploration and exploitation of space requires a long-term view, and a commitment to that view through good times and bad, that has been lacking since the Apollo program.

However, it must also be noted and acknowledged that, in another sense, certain elements of any space architecture are so fundamental, so basic to all that follows, as to be less dependent on the nature and timing of later goals and objectives. Examples of such fundamental elements are core space technology programs (e.g., power, propulsion, life support, etc.) and, in my view, reliable and cost effective transportation to low Earth orbit. In particular, the need for improvement in this latter area is so great as that we really should not defer it until longer-term architectures and developed and agreed upon. In the wake of the *Columbia* failure, we are at an especially critical juncture, where we must make a decision either to improve and upgrade the Shuttle and continue to use it for a significant period, or to plan to phase out the Shuttle and aggressively develop a new system. I favor the latter choice, but either way, a decision must be made.

Q2. NASA is relying heavily on the contractors to produce the design trade-offs and cost evaluations of the Orbital Space Plane.

Q2a. Does NASA have the management and technical depth to effectively assess the results of the contractor studies?

A2a. Yes, although it is always the case that in some cases it may be necessary to hire outside the Agency to fulfill a particular requirement. But, overall, NASA's base of technical skills is both broad and deep. It may well be, however, that this skill base has not so far been brought to bear on the OSP program.

Q2b. What recommendations do you have to strengthen NASA's capability to successfully manage the OSP program?

A2b. NASA should elevate the OSP program to maximal importance within the Agency. A reasonable schedule goal of approximately five years to first flight should be enunciated and embraced. A new development program office, reporting to the Administrator/Deputy Administrator should be established to lead the development of OSP and related systems and facilities. This office should be authorized to draw upon resources across NASA, excepting only those critically necessary to the continued safe flight of the Shuttle while OSP is in development, and should have complete responsibility within NASA for meeting OSP objectives, such objectives to be agreed upon between Congress and the Administration. A proven manager should be hired or assigned to lead this effort.

Q3. Dr. Grey's testimony state, "The only time manual control [of the Shuttle] is used today is in Space Station proximity operations and in the final phase of the landing. Both of those tasks can be accommodated by computer-operated systems."

Q3a. Should NASA seek to develop a fully autonomous Shuttle capability?

A3a. No. The only value obtained by launching a payload on the Shuttle is that of having people onboard to interact with the payload if and as necessary. If the shuttle is fully automated, then it is functionally no more capable than a conventional expendable launch vehicle, but with a significant additional penalty in terms of cost and processing time. A better option, when human presence is not required, would be to develop an automated rendezvous and proximity operations capability to fly on conventional unmanned, expendable vehicles.

Q3b. What technical barriers, if any, need to be addressed to develop a fully autonomous Shuttle?

A3b. There are no technical barriers to such a development. The only significant modification necessary is to automate the landing gear deployment process, which today is manually controlled by the Shuttle pilot.

Q4. The testimony of all three of the outside witnesses recommended the need for a "crew escape system" or "launch escape system." NASA's Level 1 safety requirement for crew transport states, "The risk of loss of crew shall be, with high confidence, lower than the Space Shuttle for the transport mission."

Q4a. Does this requirement adequately address your concern for a launch escape system?

A4a. No. The requirement in this case is too broadly stated. There are at least two highly ambiguous issues. The first is the question of what level of Shuttle reliability should be assumed. Prior to the *Columbia* accident, in October 2002, NASA stated publicly that the loss-of-crew probability for a generic Shuttle mission was 1/265. However, if this were so, and if all Shuttle flights were identical insofar as risk were concerned, then there is less than a 6 percent probability (based on Poisson statistics) that two fatal accidents could occur over the course of 113 flights. So, I submit that NASA's reliability analysis methodology is at best incomplete, and therefore the target Shuttle reliability number, upon which the OSP must improve, is unknown.

The second issue is, of course, that the amount of improvement relative to Shuttle is unspecified.

The proper approach is to specify a desired loss-of-crew probability; e.g., 1/1000, and then review the means by, and the technical credibility with which, that goal is intended to be achieved in the final design.

Q4b. Should a launch escape system requirement be spelled out in the Level 1 requirements?

A4b. Yes. That is, the requirement to have such a system, irrespective of the generic reliability of the new OSP system, should be a Level 1 requirement for the OSP. However, the details by which crew escape is to be accomplished should not be addressed at this level, but should instead be left to the discretion of the designers, and reviewed for adequacy and credibility by NASA prior to implementation. Finally, the term "launch escape system" may itself be misleading. It is equally necessary to provide crew escape capability during as much of the landing phase as possible.

These remarks should not, however, be taken to indicate that I believe crew escape necessarily to be a reasonable, or even possible, goal across the full range of flight conditions. Most flight vehicles, not excepting commercial airliners, have "dead man zones" in the flight regime, from which a safe abort in the event of an anomaly is not possible. The OSP will be no different. The goal should be to minimize them, but it should be recognized that they cannot be completely eliminated.

Question submitted by Representative Bart Gordon

Q1. Several years ago, the space transportation subcommittee of the NASA Advisory Council (NAC) recommended that: "NASA (through Congress) should give the Space Launch Initiative a program orientation to produce a robust, low-cost second generation RLV (reusable launch vehicle) by about 2015 at a specified development, test, and production cost managed in accordance with a milestone-oriented 2001–2015 schedule." However, in his written testimony, Mr. Gregory states, "NASA concluded that the economic case for a new RLV was in doubt for the foreseeable future." In the aftermath of the Columbia *accident, what do you think of the NAC space transportation subcommittee's recommendation—would it be a good way to proceed? Why or why not?*

A1. In my opinion, any new launch system development should focus on exactly the goal set forth by the NAC—a new, robust, low-cost, second-generation RLV. However, I believe the 2015 schedule goal is insufficiently demanding. A six- to seven-year development program for such an effort should be entirely adequate. A longer program risks loss of focus, encounters greater difficulty in retaining funding commitments, and will be outdated by newer technology before it flies.

Mr. Gregory is entirely correct when he notes that the economic case for a new RLV is in doubt. The demand for space launch is, like the demand for all other goods and services, a function of the cost and availability of the service. Market demand analyses for future vehicles, based wholly or in part upon the demand for today's existing launch vehicles, lack the necessary credibility upon which to base the important decisions confronting us. The situation has been likened to the task of trying to estimate the likely demand for a new bridge in a certain location, by counting the people who are observed to swim the river!

NASA does not exist to develop and build those systems for which the economic case is apparent. NASA and its products are and should be an investment in the future.

Appendix 2:

Additional Material for the Record

National Aeronautics and
Space Administration
Headquarters
Washington, DC 20546-0001

Reply to Attn of: L:MDK:L/2002-00774f

JAN 15 2003

The Honorable Ralph M. Hall
Ranking Democrat
Committee on Science
House of Representatives
Washington, DC 20515

Dear Mr. Hall:

This is to acknowledge receipt of your December 20, 2002, letter, signed jointly with Congressman Gordon, requesting a number of cost assessment reports pertaining to the X-38/Crew Return Vehicle (CRV) project and the Space Launch Initiative. We will provide these assessment reports to your staff in the immediate future.

Sincerely,

Charles T. Horner, III
Assistant Administrator
for Legislative Affairs

U.S. HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE

SUITE 2320 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515-6301
(202) 225-6371
TTY (202) 226-4410
http://www.house.gov/science/welcome.htm

December 20, 2002

The Honorable Sean O'Keefe
Administrator
National Aeronautics and Space Administration
Washington, C.C. 20546

Dear Administrator O'Keefe:

Reliable and meaningful cost estimates are required if the Congress is to understand the implications of NASA's proposed initiatives. While cost estimation for the International Space Station program has been the major focus of attention over the last year there have been several other recent cost estimate changes for which we would like additional information.

In your September 30, 2002 letter to Representative Ralph Hall, you stated that "*based on an independent assessment of the X-38/CRV project, conducted in 1999 an X-38/CRV program would cost approximately $3 billion, depending on the approach used in design development test and evaluation, and production.* The 1999 $3 billion estimate is significantly higher than the $1.3-1.4 billion estimate consistently provided to Congress in more recent years. Please provide the Subcommittee with copies of all cost assessments of the X-38/CRV program, including the 1999 independent assessment referenced in your September 30th letter, the assessments used to develop the $1.3-1.4 billion estimate provided to Congress, and any other cost assessments conducted from 1999 to the time the program was cancelled.

The "Justification for the FY 2003 Budget Amendment" recently submitted to Congress states that *the development cost of a new RLV is now expected to be well above the original $10 billion estimate. After thorough study, NASA's SLI program estimates a cost of $20 billion including production of the fleet. Four independent estimates sponsored by NASA projected a cost of $30-35 billion.*" Please provide the Subcommittee with copies of the assessments supporting the original $10 billion estimate and the SLI program's current $20 billion estimate. In addition, please provide copies of the four independent assessments referenced in the Justification that projected an RLV cost of $30-35 billion.

We would appreciate it if you could provide the requested assessment reports no later than January 13, 2003.

Sincerely,

RALPH M. HALL
Ranking Democratic Member

BART GORDON
Ranking Democratic Member
Subcommittee on Space and Aeronautics

Request For Cost Information On X-38/CRV and SLI Cost Estimates from House Committee on Science December 20, 2002

Prepared by NASA Headquarters
Code BC
Jan 13, 2003

Specific Requests

- **Provide all cost assessments of X-38/CRV Program including**
  - CRV *IPAO independent* assessment (Mar 1999) (see Enc. 1)
  - CRV acquisition cost estimate of $1.5 billion (Apr 2002) (see Enc. 2)
  - CRV acquisition cost estimate of $3 to $5 billion (Nov 2002) (see Enc. 3)
- **Provide cost SLI program estimates including**
  - RLV vehicle development cost estimate of $10 billion (Oct 1999) (see Enc. 4)
  - SLI acquisition cost estimate of $20 billion (Mar 2002) (see Enc. 5)
  - SLI independent acquisition cost estimates of $30 to $35 billion (Apr 2002) (see Enc. 6)

X-38/CRV Independent Assessment (see Enclosure 1)

- **In March 1999, at the request of the NASA PMC, the LaRC *IPAO* performed an *independent* assessment of the X-38/CRV program**
  - IA recommended that project focus on resolving high risk issues, if prototype approach was to be successful
  - IA also stated that unless attention is paid to these recommendations, significant cost & schedule overruns were probable
- **The IPAO utilized the Aerospace Corporation to perform major parts of the assessment**
  - Aerospace performed an independent cost assessment which provided two acquisition cost estimates
    - "Business as usual" estimate of ~$2.5 billion
    - "Rapid Prototype" estimate of ~$1.3 billion
    - Assumed an FY99-FY05 development program
    - Included 4 CRV production units
    - Assumed no ESA contributions

CRV Acquisition Cost Estimate of $1.5 Billion (see Enclosure 2)

- **In April 2002, the JSC X-38/CRV Project Office provided an acquisition cost estimate which totaled about $1.5 billion**
  - This was the "to-go" cost of the X-38 prototype program to implement an operational CRV and assumed refurbishment and reuse of existing X-38 assets
    - Assumed an FY03-FY12 development program
    - Included one refurbished X-38 proto-flight vehicle plus 2 additional CRV production units (total of 3 production units)
  - Assumed ESA contribution of $150M to $200M
  - Assumed substantial continued civil service effort
  - Assumed continuation of rapid prototype approach (~50% discount from historical NASA cost experience)

Cost Analysis Division

CRV Acquisition Cost Estimate of $3 to $5 Billion (see Enclosure 3)

- **In Nov 2002, NASA Headquarters Code BC performed an *independent* acquisition cost estimate of CRV**
  - Assumed X-38 design but with significant design update from X-38 consistent with an operational vehicle versus X-vehicle
  - Did not assume rapid prototyping approach for human rated system
  - Assumed an FY03-FY12 development program
  - Included 3 CRV production units
- **A range of cost was generated corresponding to 30%, 50% and 70% confidence levels**
  - 30% confidence ~$3 billion
  - 50% confidence ~$4 billion
  - 70% confidence ~$5 billion

RLV Vehicle Development Cost Estimate of $10 billion (see Enclosure 4)

- **In Oct 1999, the RLV program briefed OMB and provided a range of *preliminary* cost estimates**
  - The range included a $10 billion value
  - The $10 billion RLV was based on the assumption of a preceding $9 to $11 billion technology development program with a successful 2 stage X vehicle demo
    - Actual budget was later decreased to $5 billion
  - The content of the $10 billion estimates was basic RLV vehicle development only (excluding facilities, fleet procurement, inflation beyond 1999 and other content)
  - Cost range enveloped…
    - Included one LH engine development
    - Assumed Bimese vehicle configuration (one airframe development which serves as booster and orbiter)
  - The purpose of this cost analysis was to highlight the effects of technology investments

Cost Analysis Division

SLI Program Acquisition Cost Estimate of $20 billion (see Enclosure 5)

- **In Mar 2002, the SLI contractors provided SLI acquisition cost estimates**
  - The resulting cost estimates ranged from $17 billion to $23 billion
    - Based on $5 billion predecessor technology program
  - The content of this estimate was full acquisition cost including vehicle development, facilities, fleet production, etc.
  - Cost range enveloped…
    - Optimized two stage vehicle configuration (dissimilar airframes for as booster and orbiter)
    - Two engine developments (RP and LH)
  - $20 billion was mentioned in the FY03 Budget Amendment as representative of this cost range

Cost Analysis Division

SLI Independent Acquisition Cost Estimates of $30 to $35 Billion (see Enclosure 6)

- **In April of 2002, at the request of the MSFC Center Director, the MSFC Engineering Cost Office and the Systems Management Office Directorate led an assessment of SLI which produced 4 *independent* cost estimates of the acquisition cost of SLI**
- **Estimates were independently developed by four parametric cost modelers**
  - The Aerospace Corporation
  - SAIC using the NAFCOM cost model
  - Price Systems using the Price Model
  - MSFC Engineering Cost Office using the COSTAR cost model
- **These estimates included acquisition cost through the first flight article ("cost through first flight")**
  - Cost assumed
    - Optimized two stage vehicle configuration (dissimilar airframes for as booster and orbiter)
      - Two engine developments (RP and LH)
- **The resulting acquisition cost range was ~$32 billion to ~$34 billion**
  - This was reported out as a $30 billion to $35 billion range

Enclosure 1
1999 Independent Assessment of the X-38/CRV

AEROSPACE REPORT

NO ATR-99(7647)-1

INTERNATIONAL SPACE STATION (ISS) X-38/CREW RETURN VEHICLE (CRV) PROJECT INDEPENDENT ASSESSMENT FINAL REPORT

31 March 1999

Coordinated by

B.H.WENDLER
Vehicle Systems Division

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Langley Research Center
4 S. Marvin St.
Hampton, VA

Contract No. NAS1-99050
DR: T-2

Engineering and Technology Group

1 INDEPENDENT SCHEDULE ASSESSMENT

Scheduling data for the X-38/CRV Program were presented at the last major Technical-Interchange Meeting (TIM) on 1/22/99 at JSC. Because of the relatively short time between the time the data was available and the end of the assessment the analysis was focused on 2 primary areas: a schedule slippage analysis was performed to determine the rate of schedule creep and a software schedule analysis was performed. The team chose to concentrate on the software area because the software schedule was the least defined of all functional areas and experience has shown that software is typically a "tall pole" for flight programs.

1.1 Data Collected and Models Used

1.1.1 Slippage Analysis Data/Models

Three issues of program schedules were provided to the assessment team, which were then summarized on an EXCEL Spreadsheet that included completion dates and task duration from each version of the schedule. The program provided schedules dated 8/13/97, 3/27/98, and 12/11/98. The spreadsheet, see Figure 4.1-1 at the end of the section, was created for use in this analysis.

1.1.2 Software Schedule Analysis Data/Models

The Aerospace Cost and Requirements Department conducted the software schedule analysis using a COTS Tool, SEER-SEM, which Aerospace has used for a number of years and its results have favorably compared against actual experience. Tool inputs were coordinated with and agreed to by the X-38 Software Development Lead engineer and are discussed later in this report. The SEER-SEM knowledge base contains data from 209 spacecraft and space related ground system software development projects. This knowledge base data was obtained from the USAF Space and Missile Center and MITRE Corporation.

The assessment team was also provided with the latest copy of the project Software Development Plan for review and comment.

1.2 Assumptions

The assumptions listed below summarize the inputs to the Software Schedule Analysis Tool. A copy of the input form is attached to this report. These were reviewed with and agreed to by the program software development lead engineer. There were no assumptions made for the slippage analysis.

- Platform – Unmanned Space
- Application – Command and Control
- Acquisition Method – New Development
- Development Method – 25% COTS, 25% New Code, 50% Prototype Reuse
- Standards - ISO 9001
- SLOC (27 factors) - 100K

- Environment (9) – Very Modern
- Requirements – Fairly Volatile
- Complexity - High
- Schedule Needs - Nominal
- Target System – Well Known
- Reusability – N/A
- Personnel (7) – Very High Quality

1.3 Findings and Maturity Assessment

1.3.1 Schedule Slippage Analysis Findings

19 schedule line items have slipped an average of 9 months each since 8/13/97

Some task durations are gyrating wildly e.g., Aft Fuselage & Port Fin Installation

- 8/13/97 Version - 65 weeks
- 3/27/98 Version - 27 weeks
- 12/11/98 Version - 24.6 weeks
- e.g., System Installation & Test
- 8/13/97 Version - 53.8 weeks
- 3/27/98 Version - 22 weeks
- 12/11/98 Version - 55 weeks

1.3.2 Software Schedule Analysis Findings

2 Model runs had to be made due to erroneous assumptions made for 1st run

Run #1 results
50% probability that schedule span will be 36.67 months which is very close to the 36 month schedule contained in the Software Development Plan

The assumption that there was a single Computer Software Configuration Item (CSCI) was incorrect (per the software development plan) so a second model run was called for which allowed for parallel development of multiple CSCIs.

Run #2 results
An estimate of a 50% probability for a 28 month development period. SEER-SEM also estimated a 90% probability of meeting a 36 month schedule

1.3.3 Other Schedule Findings

During the above mentioned TIM it was noted that there will be multiple organizations and countries supporting the CRV program and each will be making significant contributions of vehicle capabilities. Since NASA will be integrating the overall CRV program it is felt that the amount of design and development work assigned to the European Space Agency (ESA), the prime contractor, and GFE from NASA itself poses a high risk without an integrated schedule and Work Breakdown Structure (WBS).

The projects Software Development Plan was reviewed by Aerospace software experts who concluded document was very high quality and if the plan is followed the software development project is well in hand.

1.4 Recommended Risk Mitigation

The amount of design work assigned to ESA, combined with significant work assigned to the production contractor and GFE elements poses a high risk if a program level integrated schedule and corresponding program level work breakdown structure is not developed prior to award of the production contract and then used by NASA to manage the integration of the program.

The software schedule is risky if (AND ONLY IF) the Software Development Plan is not followed or cannot be implemented. This plan is a very high quality document and it is estimated there is a greater than 50% chance of completing the software development in less than the allocated 36 month schedule. This is expected if the plan can be implemented as written and the risks/shortcomings identified in the plan and listed below can be overcome. Failure of management adequately resolve the below listed issues will inevitably result in costly delays:

- Fault Tolerant Parallel Processing System (FTPP) being developed by Draper Labs
- Use of COTS
- Shortage of approximately 30 software development personnel
- Immaturity of requirements definition
- Fiscal restraints delaying purchase of needed software integration and test equipment

Perform a critical path analysis and establish more robust and rigid schedule controls in order to eliminate or at least reduce the slippage rate.

Task Name	8/22/97 Version	Duration (wk)	3/27/98 Version	Duration (wk)	12/11/98 Version	Duration (wk)	[illegible]
[redacted]							
Secondary Structure Manufacture & Install	6/24/98	21.6	10/9/98	30			
Nose Structure Installation					8/21/99	4	1/1/00
Landing Gear Manufacture & Install			3/1/99	[illegible]	6/1/99	13.2	
[redacted]							
Software					11/29/00	[illegible]	
[redacted]							
DFS Testing (Flight Control Testing)			12/1/99	[illegible]	4/9/00	4	[illegible]
[redacted]							

Figure 4.1-1.4-1 X-38 Vehicle 201 Schedule Status

2 INDEPENDENT COST EVALUATION

2.1 Model Description and Cost-estimating Procedure

The Aerospace Launch Vehicle Cost Model (LVCM) was the primary tool used to generate CRV cost estimates. LVCM operates on programmatic data (development and launch schedules and flight quantity), stage data (propellant type and weight, design status and operations mode) and subsystem data (mass properties and commonality information related to existing subsystems). Model output consists of estimated costs for Research, Development, Test & Evaluation (RDT&E, or NASA, DDT&E), average unit production, and operations (launch, flight and recovery). RDT&E and production costs are estimated at the subsystem level, operations costs at the vehicle level. Included in each cost item is its pro rata share of system engineering, program management, data, system test, quality assurance and integration. Actual cost data underlie the LVCM, including data from programs such as Centaur, Titan, Apollo and the Space Transportation System.

A separate analysis of facilities and transportation and handling related costs was performed. This analysis is documented in Aerospace IOC No. 99.5533.CCP-3 (Aerospace).

2.2 Assumptions and Inputs

To produce the CRV cost estimate, LVCM was operated in a mode that assumed a winged-recovery vehicle. This was accomplished within the cost model by accessing relevant cost-estimating relationships for each subsystem. Launch and flight operations costs were adjusted to reflect the essential payload nature of the CRV during initial launch and subsequent flight operations, as contrasted with a launch vehicle propulsive stage required to achieve orbit. Estimates are provided in current year dollars and, as indicated in Figure 5.2-1, exclude ESA contributions.

- Independent estimates of Development, Production and Operations cost use the Aerospace Launch Vehicle Cost Model (LVCM)
- LVCM based on AF and NASA programs such as Centaur, Titan, Shuttle and Apollo
- LVCM inputs are vehicle and subsystem oriented
  - Launch quantity and schedule
  - Mass properties by subsystem
  - Commonality and previous quantity information by subsystem
- LVCM output
  - Launch schedule and Production quantities
  - RDT&E, Production and Operations cost by vehicle and subsystem
  - Cost estimates are provided in current year dollars
- Estimates exclude ESA contributions

Figure 2.2-1 Analysis Method

2.3 Results

Two CRV acquisition scenarios have been considered for cost analysis using the LVCM, as reflected in Figure 5.3-1 (see Appendix A for cost category definitions). Acquisition is defined as completion of CRV RDT&E (DDT&E) and operational deployment of four operational CRV flight articles. The Rapid Prototype scenario, currently underway, assumes that the V-201 reentry test vehicle will essentially qualify all subsystems for subsequent application to the four operational CRVs. A second scenario, employing Business-as-Usual (BAU) development and production procedures, may have to be partially or fully implemented if the V-201 test program reveals problems that lead to a departure from the currently-evolving design and rapid-prototype process. In that case, costs are expected to approach those of traditional NASA acquisition programs as shown in the BAU columns.

	$M Current Years							
	Non-recurring		Recurring				Total	
	RDT&E		Cost per Flight (4 Flights)		Total, 4 Flights			
Operational Crew Return Vehicle (CRV)	Rapid Prototype	Business as Usual (BAU)	Rapid Prototype	BAU	Rapid Prototype	BAU	Rapid Prototype	BAU
CRV	212	1132	198	214	792	856	1004	1988
Launch Operations	10	20	10	10	40	40	50	60
Flight Operations	5	5	2	2	8	8	13	13
Facilities Mod	4	4	0	0	0	0	4	4
Spares	0	46	21	23	84	92	84	138
Software	5	31	0	0	0	0	5	31
SE&TG Support	4	40	13	16	52	64	56	104
Government Support	7	70	8	10	32	40	39	110
Total Acquisition Cost	247	1348	252	275	1008	1100	1255	2448

Figure 2.3-1 LCC from ACRV to 5 years Ops Run-out

Potential bridge effort costs, as enumerated in Figure 5.3-2, are shown at subsystem and vehicle levels and are represented by the difference between Business-as-Usual (BAU) and Rapid Prototype scenarios. Bridge effort costs represent potential additional costs incurred by the Operational CRV program should the currently-evolving design and rapid prototype process encounter problems with the V-201 reentry test vehicle that will not permit the qualification of subsystems or the complete vehicle. As a consequence, a departure from rapid prototyping to traditional acquisition procedures may be required on a subsystem basis or for the complete vehicle.

Operational CRV		RDT&E Cost Estimates $M Current Years		
Vehicle Subsystems & related RDT&E Items	Weight (lbs)	Rapid Prototype (RaPr)	Business as Usual (BAU)	Potential Bridge Effort Required (BAU-RaPr)
Structure	11552	50	212	162
Thermal	1585	4	41	37
Reentry Protection	1131	2	49	47
Landing System	6350	33	175	142
Electrical Power	2086	3	13	10
Electrical Wiring	633	2	42	40
Guidance & Control	90	21	53	32
Data Handling	408	5	49	44
Instrumentation	241	1	25	24
Communications	106	2	19	17
Propulsion System	5063	8	8	0
Reaction Control System	403	3	52	49
Adapter	600	9	15	6
Propellant	1981			
Dev Test Units		60	197	137
GSE & ASE		3	79	76
Ground Test Prog		6	101	95
Vehicle Stage Total	32149	212	1132	920

Figure 2.3-2 Subsystem DDT&E Cost Estimate

Note that potential bridge effort costs assume that valuable design and test information has been acquired through the rapid prototype process. This assumption allows simple subtractions to be performed as shown in Figure 5.3-2. However, in the unlikely event that particular subsystems, or the complete vehicle, must be entirely redefined the bridge effort costs could approach those shown in the BAU column.

Figure 5.3-3 provides funding requirements by category and by fiscal year for the Rapid Prototype scenario. Note that the cumulative amount through FY 99 includes all budgeted funds for V-201. Data in the figure excludes maintenance and refurbishment operations during subsequent years, funding for which is primarily a function of the operational return philosophy.

$M Current Years

	cum thru FY99	FY00	FY01	FY02	FY03	FY04	Total thru 04
DDT&E	100	16	63	53	11		243
Procurement		27	192	390	290	54	953
Operations					13	42	55
Facilities Mod		2	2				4
Total	100	45	257	443	314	96	1255

Figure 2.3-3 Funding by Acquisition Category

The current NASA budget is shown for comparison with the acquisition scenarios considered in the independent analysis. The Rapid Prototype scenario assumes the V-201 qualifies all subsystems, yielding a build-to-print design for the four follow-on flight vehicles. The LVCM fiscal year cumulative funding profile for the Rapid Prototype scenario closely follows the NASA budget. Under the BAU scenario, that is, if the previous assumption regarding V-201 proves to be incorrect, schedules as well as the funding profile will be severely affected, as shown in Figure 5.3-4.

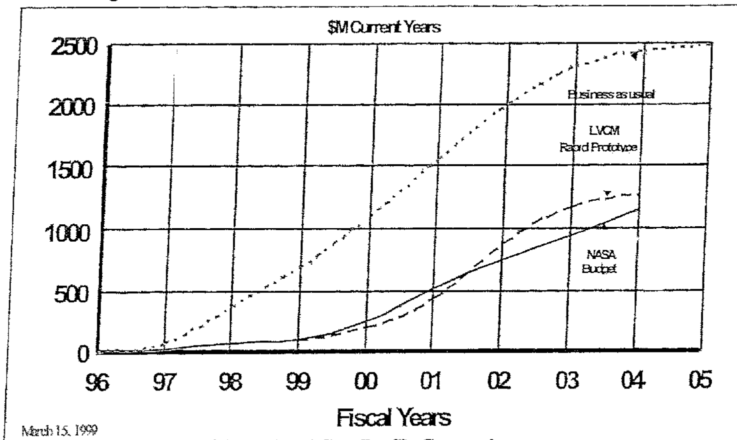


Figure 2.3-4 Cost Profile Comparisons

Figure 5.3-5 provides typical funding requirements by major cost category and fiscal year for the BAU scenario had it commenced at approximately the same time as the V-201 program. These data, when overlaid on the Rapid Prototype funding curve (provided in Figure 5.3-4) show that large amounts have either been avoided (saved, because the rapid prototype process succeeded) or will be required (needed, because the rapid prototype did not succeed).

	FY97	FY98	FY99	FY00	FY01	FY02	FY03	FY04	FY05	Total thru 05
DDT&E	75	217	220	239	251	196	44			1242
Procurement	0	30	143	180	190	230	223	115	26	1137
Operations					12	13	14	13	13	65
Facilities Mod				2	2					4
Total	75	247	363	421	455	439	281	128	39	2448

Figure 2.3-5 Cost Category by Current Year

2.4 Cost Model Basis

In many instances, certain subsystems may draw from previous programs and incorporate all or a portion of a given subsystem with few changes in design. Engines are an obvious example where interchangeability is often realized with little or no modification. Other subsystems rarely are interchangeable — structure, wiring, reentry protection, thermal and adapters — are examples. Strictly speaking, exact part number matches need to be identified before commonality can be correctly attributed to the subsystem in question. However, a ratio of existing-parts weight to total subsystem weight can also be used.

Commonality and previous quantity are related. Previous quantity indicates how many of the same subsystems have been previously built. For an entirely new subsystem, there is zero commonality with any previously developed subsystem; hence the previous quantity must also be zero.

The commonality percentage input directly operates on RDT&E to reduce design and testing cost. It also influences production cost by altering learning curve selection. The previous quantity input indirectly operates on production by adjusting the point of entry on the learning curve for the common portion of a subsystem.

The Rapid Prototype scenario assumes that V-201 subsystems are closely akin to the operational CRV; thus, commonality between V-201 and the follow-on CRVs is assumed to be very high for all subsystems. In contrast, the BAU scenario assumes that an operational CRV would be designed, developed, produced and operated along the lines of a typical NASA program.

From Figure 5.4-1, the commonality and previous quantity columns show the relationships between the BAU and Rapid Prototype assumptions. In the BAU case, subsystems that are a function of the CRV's unique features, such as its landing, structure, reentry protection and thermal subsystems, would be entirely new designs with zero commonality to previous vehicles. Certain avionics and propulsion subsystems typically have drawn on previously developed subsystems.

	BAU / RAPID PROTOTYPE	
Operational CRV Subsystem	Commonality (% common)	Previous Quantity
Structure	0 / 85	0 / 1
Thermal	0 / 90	0 / 1
Reentry Protection	0 / 95	0 / 1
Landing System	0 / 90	0 / 2
Electrical - Power	75 / 95	50 / 50
Electrical - Wiring	0 / 95	0 / 1
Guidance & Control	50 / 90	10 / 10
Data Handling	50 / 95	10 / 10
Instrumentation	0 / 95	0 / 1
Communications	50 / 95	50 / 50
Propulsion System	95 / 95	200 / 200
Reaction Control System	0 / 95	0 / 1
Adapter	0 / 50	0 / 2

Figure 2.4-1 Model Inputs

Operational CRV usage-dependent costs shown in Figure 5.4-2 are added to acquisition costs shown in Figure 5.3-1 in order to obtain total CRV system life cycle cost. A primary cost driver of these incremental costs is the number of times that the CRV is actually used to return astronauts, with each emergency reuse incurring a $37M recovery, refurbishment and relaunch cost. It has been assumed that portions of the landing and thermal protection subsystems would be replaced after emergency reentry. Consequently, ESA would also be involved, however, no cost has been included for their effort, which is estimated by the LVCM to total approximately $110M for five refurbishments (leading edges and landing gear).

Usage-dependent Items: Assumes 4 Units deployed, with total of 2 - 5 CRV Reuses Over 25-Year Life Cycle								
Transportation &	Non-recurring		2 Trips by Ground	2 Trips by Air	5 Trips by Ground	5 Trips by Air	Optimistic 2 Gnd Trips	Pessimistic 5 Air Trips
Handling	N/A		0.15	0.38	0.4	0.9	0.2	0.9
Operations &								
Maintenance	Non-recurring		25 Years (Annual)				25 years	
a) Facilities	N/A		97 (3.9)				97	
b) CRV Recovery	Non-recurring		Optimistic 2 Reuses	Pessimistic 5 Reuses	Optimistic 2 Reuses	Pessimistic 5 Reuses	Optimistic 2 Reuses	Pessimistic 5 Reuses
Refurbishment & Relaunch	N/A		74	185	74	185	74	185
Total CRV System Life Cycle Cost	247	1348	1179	1382	1179	1383	1426	2731

Figure 2.4-2 Total Run Out LCC

Various operations and support cost categories, enumerated in Figure 3.3-1, are defined in Appendix A.

Programmed return of each CRV by the Shuttle Orbiter, nominally assumed to occur after three years at the ISS, should not involve major refurbishment; hence these costs are not included. A total of two to five emergency reuses have been hypothesized for illustrative purposes as no guidelines were provided outlining the number of anticipated reuses. If it turns out that the CRV is deployed but never utilized, the primary usage-dependent cost is CRV facilities maintenance costs, at an estimated $3.9M annual rate. Transportation and handling costs, after emergency reentry or programmed return, are estimated to be relatively negligible. The details of facilities maintenance and transportation and handling costs can be found in Aerospace IOC No. 99.5533.CCP-3.

3 PROJECT RISK ASSESSMENT

It is the conclusion of the IA team that the project must focus on resolving high-risk issues if prototype approach is to be successful. Experience has shown that transitioning from rapid prototyping to production needs more discipline than traditional projects which require less of a culture change. Similar projects that did not transition became unexecutable.

3.1 High Risk and High Reward Assessment

Traditional aerospace procurement programs involve a requirements definition stage, a concept development activity with requirements decomposition to design aspects and then conducting design trades, progressive definition of the interface and design to proceed into a build, and then verification of the concept prior to or using the initial production items. Figure 6.1-1 illustrates this concept as streamlined based on acquisition reform, but basically still requirements flowdown baseline. Figure 6.1-2 illustrates a rapid prototype approach, typically driven by design to cost and a need to discover the requirements.

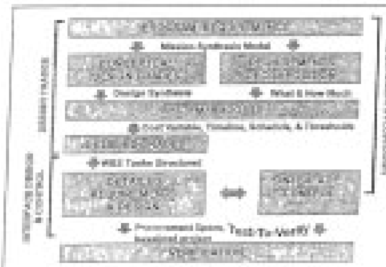


Figure 3.1-1 Formal Acquisition Approach

Figure 3.1-2 Rapid Prototype Approach

The Project in this case started with a more open definition without firm requirements, allowing the late changes in requirements, for example, from 4 crew to 7 crew and other major changes to be accommodated with significantly less cost than would occur on a traditional program approach. The project uses rapid prototype techniques to assemble concepts and functions together using Off-the-Shelf or Non-Development Items to the maximum extent possible. Hardware and software testbeds are used to rapidly learn and feedback the capability of the prototype and implement design changes. The progressive demonstrations build confidence in the design synthesis process and higher and higher fidelity prototypes are developed. The goal of this effort is to achieve a high quality build to print entrance into production, instead of a build to specification document.

Figure 6.1-3 illustrates the cost savings aspect of the rapid prototype in the early development of the project. Most of the savings in cost and schedule occur in the rapid development cycle prior to the transition to a more formal "build-to-print" focus of the acquisition. The transition for the X-38 project team is expected to introduce more interface control aspects for both internal and external systems. Evidence of this is already seen with the document SSP 50306 incorporation of numerous ISS interface requirements. The transition also involves a clear definition of risks for scope and prioritization of tasks in the delta requirements and designs to baseline the project. Included are risks discovered from a test failure to be addressed by a fix and the next test, but those that develop from project fragmentation, interfaces, process, and performance uncertainty. In addition, rapid prototype tools involve assumptions that need to be validated against the more refined models and test results, (example, mean plus margin and 4 DOF analysis versus 6 DOF dispersed analysis). ***The IA team's review found the transition structure was not being approached initially with the due diligence necessary for success compared to other rapid prototype programs.***

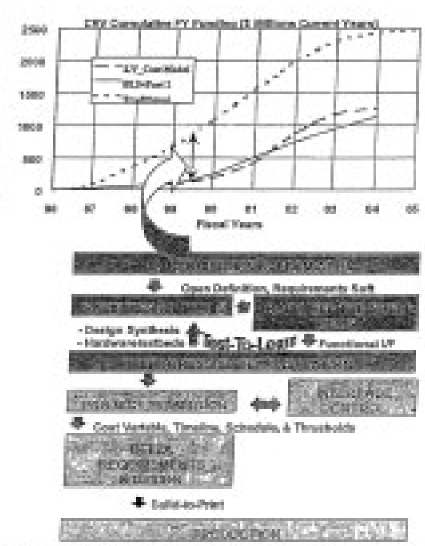


Figure 3.1-3 Cost Savings Using Rapid Prototyping

The failure of the rapid prototype X-38 to be effective towards a CRV build could be caused by any number of scenarios. One might involve the following kind of elements, where the Part 1, Delta Requirements and Design effort is used to solve rapid prototyping problems, not the CRV issues, focusing 80 percent of the effort on only 20% of the problem. Another scenario could involve system budgets that exceed the weight or propellant limits to where the weight reduction effort "breaks" the design requiring elaborate materials and lightweight subsystems. Still another scenario could involve a build-to-print with an unclear build to specification so it can not be proven the application satisfies the mission and the discovery of requirements effort would have to continue with the CRV on-orbit. Figure 6.1-4 list some examples of quicker, better, cheaper projects which discovered failure rather than success in their mission.

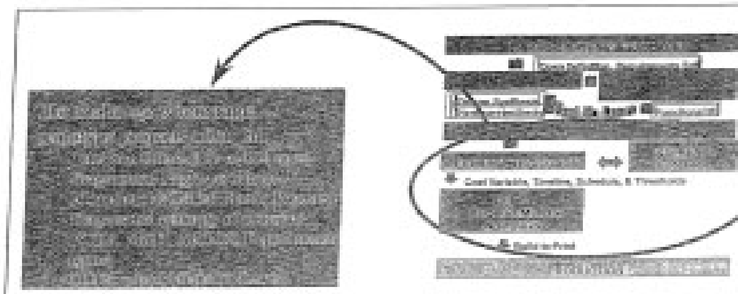


Figure 3.1-4 Where Rapid Prototype Programs Can Fail

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3.2 Recommendations

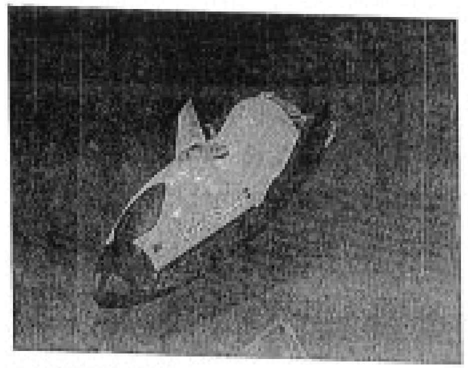
Based on the assessments, the IA rates the project as "high risk" with a significant cost savings being demonstrated against this risk. The IA team highly recommends a six-month maturity gate for this project so the project can prove it can enter into the transition effort with an executable approach. The gate should also include items the project itself identifies over the time remaining in Phase 0 to have a complete gate. Finally, the bridge items identified to certify the vehicle need action plans, starting with modifying the Part 1 RFP to address an approach that can bridge the X-38 to the CRV. Unless attention is paid to these recommendations, significant cost & schedule overruns are probable. NASA could lose up to $1B savings over traditional approach and the corporate memory of how rapid prototyping can work for other projects. The team believes a more rigorous System Engineering process for transitioning to CRV will enhance probability of success of the project and contingencies should be planned if critical 6-month gate items are not achieved.

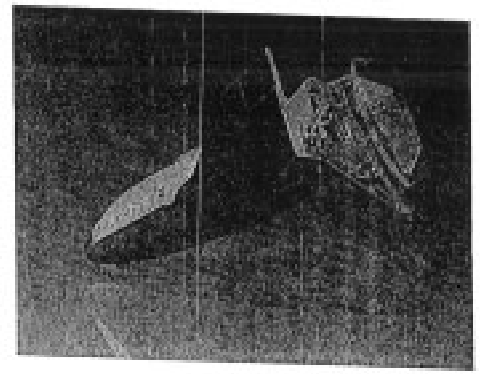
Enclosure 2
X-38/CRV $1.3 Billion-$1.4 Billion Estimate

X-38/Crew Return Vehicle (CRV)

EA3/John F. Muratore
LE/Cindy L. Garren

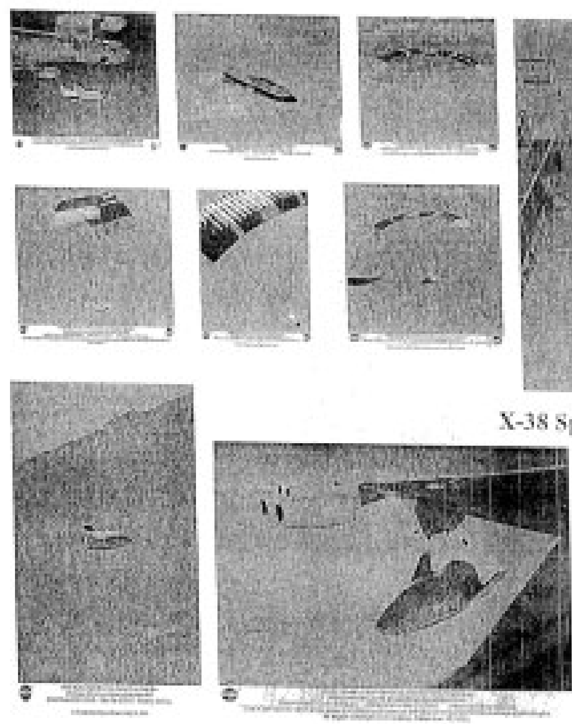
17 April 2002



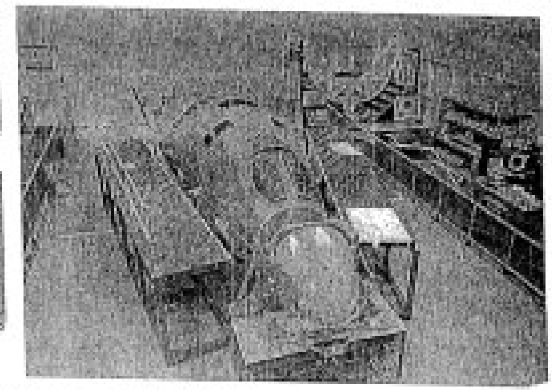


LOW COST, HIGH-TECH SPACE RESCUE
X-38 Specifications
Crew Return Vehicle (CRV) Prototype
Lifting Body with Parafoil final descent and landing
Length: 30 ft.
Width: 15 ft.
Monopropellant Hydrazine in disposable Deorbit Module
Weight: 33,400 lbs.
Speed Range: Mach 25 to 0
Human Rated Design
7-person capacity

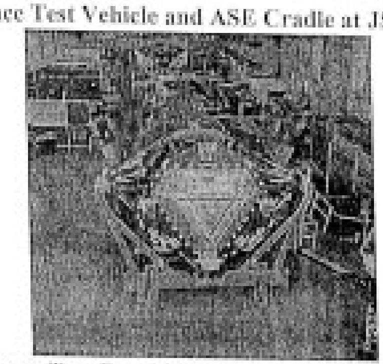
A prototype for the CRV designed and built primarily by civil servants at JSC



Eight Atmospheric Flights To date with three increasing levels of complexity



X-38 Space Test Vehicle and ASE Cradle at JSC

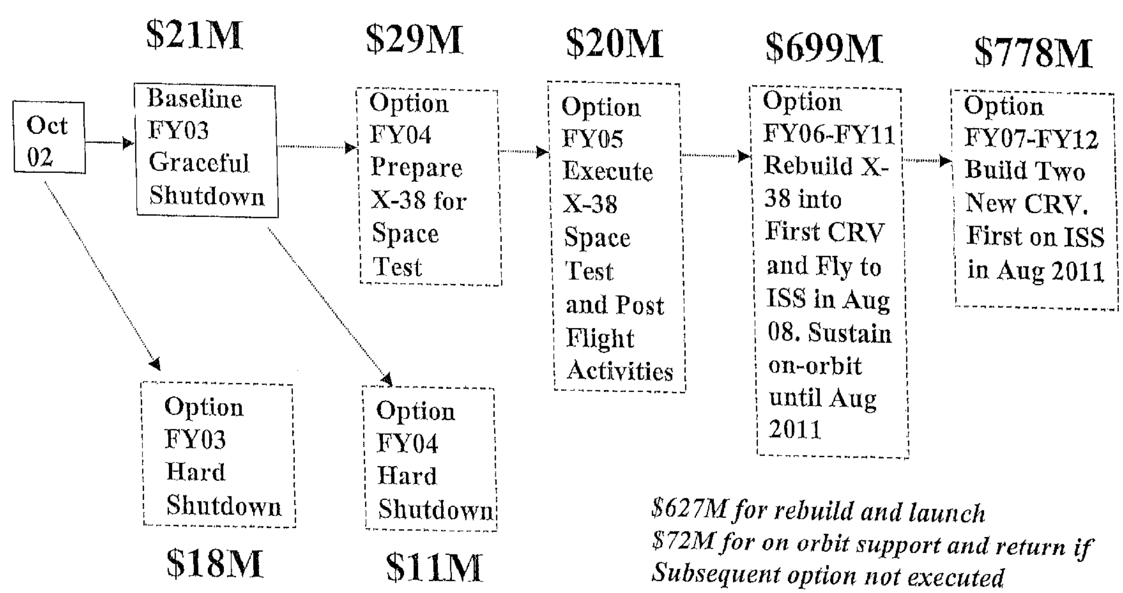


X-38 Space Test Deorbit Module Mated To Lifting Body at JSC in Mobile Transporter

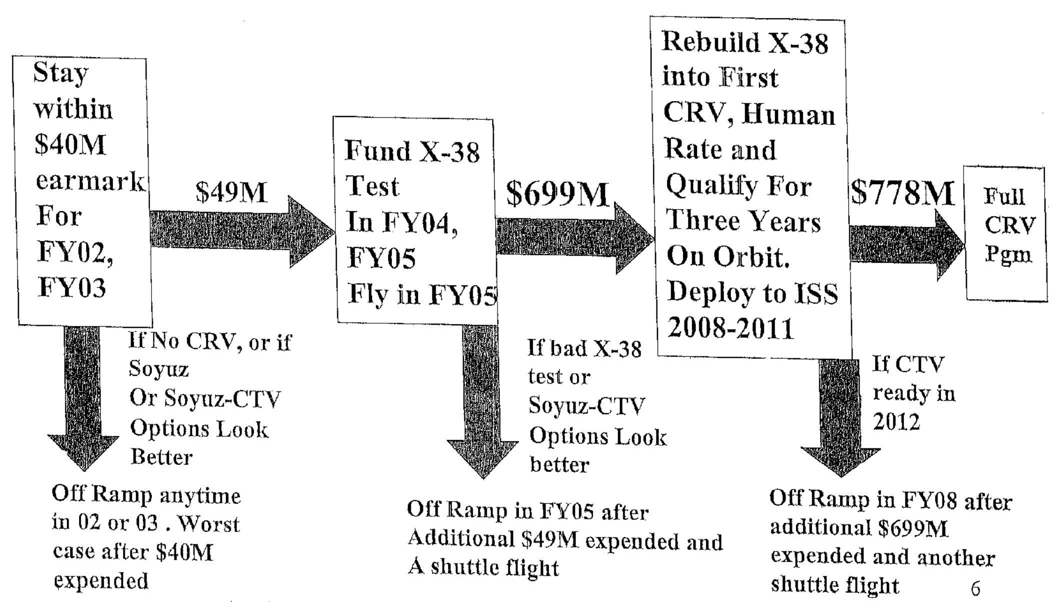
Overview – Current X-38/CRV Budget

- In POP 03 the X-38/CRV submits requirements against a baseline that only includes FY03
- Remaining POP 03 submit is six different options in subsequent years
- Each option has specific assumptions and covers specific years
- The options allow the ISS Program to see the costs for a wide variety of potential scenarios
- This provides NASA a set of "off-ramps" to decide on different implementation options based on project performance and external factors
- The options also provide ISS the opportunity to buy into the CRV activity in steps.
  - At each step, previous performance and estimates of cost to complete can be reviewed and alternatives selected if performance or cost estimates do not meet ISS requirements
- This "modularization" is different than previous submits. Previous submits assumed a single flow of activity
  - This modularization is less efficient than previous submits and there is some total cost growth

POP 03 Summary For X-38/CRV



Incremental Strategy With Off Ramps Protects NASA's Options



Additional ESA contribution could lower $699M and $778M bill

Yearly Phasing – All Options

	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08	FY 09	FY 10	FY11	FY 12	FY 13	TOTAL
FY 03 Graceful Shutdown	**21**											**21**
FY 03 Hard Shutdown	18											**18**
FY 04 Prep X-38 for Space Test		**29**										**29**
FY 04 Hard Shutdown		11										**11**
FY05 Execute Space Test and Post Test			**20**									**20**
FY06-FY11 Rebuild X-38 and Deploy to ISS				**229**	**229**	**169**	30	24	18			**699**
FY 07-FY12 Build Two Additional CRV					**51**	**60**	**185**	**189**	**193**	**100**	**0**	**778**
Full Implementation Options Total	**21**	**29**	**20**	**229**	**280**	**229**	**185**	**189**	**193**	**100**	**0**	**1475**

Bold shows options which would implement a full CRV program

FY09-FY11 funding in the Rebuild X-38 option is only required if Production program is not underway. This represents minimum sustaining engineering and operations costs for the rebuilt X-38 on orbit extracted from the production CRV budget

Yearly Milestones

- Aug 04 – X-38 delivered to KSC
- Jan 05 – X-38 space test
- Feb 05 - Release Statement of Work For CRV prime contractor
- Oct 05 – X-38 rebuild starts. CRV Prime contract starts.
- Oct 07 – CRV berthing adapter delivered to KSC
- Early 08 – CRV berthing adapter launched to ISS (after node 3)
- Apr 07 – SRR for production CRV
- Dec 07 – PDR for production CRV
- Mar 08 – X-38 rebuilt to CRV delivered to KSC
- Aug 08 – X-38 rebuilt to CRV flown to ISS
- Nov 08 – CDR for production CRV
- Mar 11 – First production CRV delivered to KSC
- Aug 11 – First Production CRV exchanged on ISS for X-38 rebuilt as first CRV. X-38 based CRV is retired.
- Sep 12 – Second production CRV delivered to KSC
- Aug 14 – Second production CRV exchanged on ISS for first Production CRV. First production CRV is returned to earth and refurbished.
- Aug 15 First production CRV refurbished
- Aug 17 – First production CRV (refurbished) is exchanged on ISS for second production CRV. Second production CRV is returned to earth and refurbished.
- Aug 18 Second production CRV is refurbished
- Aug 20 - Second production CRV exchanged on ISS for first Production CRV. First production CRV is returned to earth.
- Aug 23 – Second Production CRV is returned.

Assumptions

- All budgets have been escalated with the standard OMB inflation rates
- 20% unallocated reserve is maintained through all DDT&E activities at the CRV Project level.
- A 10% unallocated reserve on sustaining engineering activities is maintained at the CRV Project level
- Upgrades to systems for supportability are included at two points.
  - Major systems are upgraded when the X-38 is upgraded to the first CRV
  - Major subsystems are upgraded again 3 years later when the two production CRVs are built
- A CRV Prime contractor will be responsible for upgrading the X-38 to an operational CRV and for producing two new production CRVs.
- CRV Prime contract was assumed to be a cost plus arrangement and a 10% fee was assumed in the budget.
- Personnel for the CRV Prime were estimated at a $200k/FTE rate in FY02 dollars and escalated per the OMB tables.
- One full shipset of subsystem spares is explicitly budgeted for the X-38 rebuilt into the CRV. No structural spares are assumed.
- One full shipset of subsystem spares is explicitly budgeted for the production CRVs along with an unallocated logistics budget equivalent to a second shipset of spares.
  - Unallocated budget will cover any structural spares as well as life limited items (batteries, parachutes, etc...)
- This budget assumes ESA contribution of a minimum set of items in a barter arrangement ($150M-$200m).
  - A larger ESA contribution has been under discussion and has the potential to lower these budget requirements in FY06-FY12.

Civil Service FTE		FY 03	FY 04	FY 05	FY 06	FY 07	FY 08	FY 09	FY 10	FY 11	FY 12	Total
FY03 Baseline Graceful Shutdown	*JSC*	*85*										
	DFRC	*25*										
	MSFC	*2*										
	KSC	*2*										
FY03 Option Hard S/D	JSC	25										
FY04 Option Prep X-38 For Space Test	*JSC*		*120*									
	DFRC		*30*									
	MSFC		*2*									
	KSC		*5*									
FY04 Option Hard S/D	JSC		25									
FY05 Option Execute Space Flight Test and PostFlight	*JSC*			*100*								
	DFRC			*25*								
	MSFC			*2*								
	KSC			*10*								
FY06-FY11 Option Rebuild 201 and Deploy To ISS	*JSC*				*60*	*30*	*30*	*10*	*10*	*10*		
	DFRC				*40*	*40*	*40*	*10*				
	MSFC				*5*	*5*	*5*	*5*	*2*	*2*		
	KSC				*tbd*	*tbd*	*tbd*	*tbd*	*tbd*	*tbd*		
FY07-FY12 Option Build two additional CRV	*JSC*					*10*	*10*	*30*	*30*	*30*	*30*	
	DFRC											
	MSFC											
	KSC											10

Overview – Cost Estimating X-38/CRV

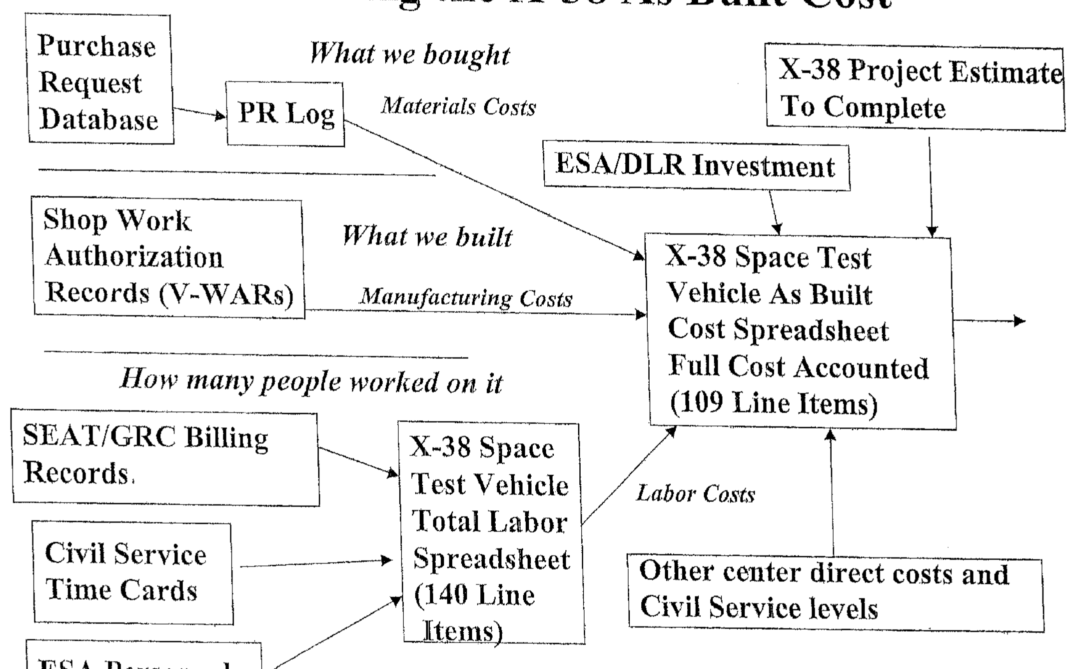
- The X-38 Space Test Vehicle as prototype CRV
- As Built Costs for the X-38 Space Vehicle
- Comparison of the As Built X-38 Space Test Vehicle Costs to a NAFCOM model of X-38 Space Test Vehicle Costs
- CRV Cost Model based on the X-38 Space Vehicle As Built Costs
- Results of LaRC/Aerospace Independent Assessment Cost Model for CRV
- ESA current and potential future investments in CRV
- Risks and Threats

X-38 Space Test Vehicle Status

Product	Total		In Manufacturing	Installed	To Go
Primary Structure	1509 Total Parts	1365 Fabricated	165	1200	144 Parts (10%)
Primary Structure	874 Total Drawings	740 Drawings Released			134 Drawings (15%)
Secondary Structure	1592 Total Parts	1157 Parts Fabricated	56 Parts	1037	555 Parts (35%)
Interconnect Wiring	13,000 Projected Total Wires	9865 Drawings Released			3135 Design (24%)
Interconnect Wiring	13,000 Projected Total Wires	7994 Manufacturing Complete	1871 in wiring fabrication	6224 routed 5676 Terminated	7234 (manufacture and install) (55%)
Thermal Protection System - Tiles	1246 Total	803 Fabricated	36	530	407 (32 %)
Thermal Protection System - Blankets	75 Total	13 Fabricated	43	5	19 Design (25 %)
Flight Software – All Systems	200,655 Lines Of Code Total Projected	129,983 Current Lines Of Code Released		60,000 lines have been run on vehicle	70,642 Lines of Code (35 %)
Flight Software – GN&C Only	73,114 Lines Of Code Total Projected	69,156 Current Lines of Code In test	40,617 Lines of Code Released		32,497Lines of Code (44 %)
Subsystem Parts – Make and Buy	1823 Total Parts	1702 Received			121 (6 %)

Overall we estimate vehicle is between 65 - 75 % complete depending on which subsystem you evaluate. ***Current status provides good basis for X-38 estimate to complete and CRV equivalent costs***

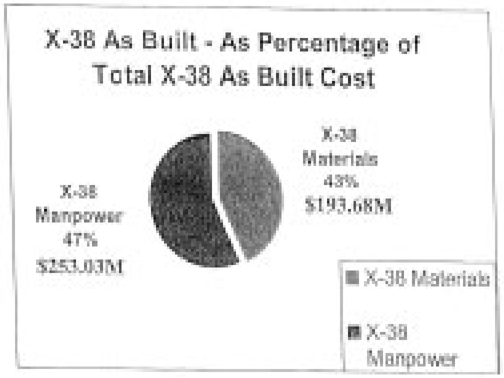
Calculating the X-38 As Built Cost

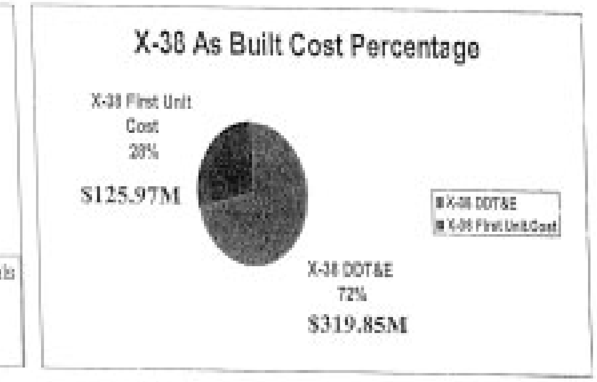


- All costs are traceable to records in the accounting system
- Assumed $200k/ CS FTE to get full cost accounted cost

13

X-38 As Built – FY05 Launch





- Numbers above are full cost accounted with $200k/Civil Service FTE
- Direct Cost in NASA budget was/will be $243M
- Total Civil Service FTE-Years was/will be 979
- Detailed Civil Service FTE is in backup materials
- Detailed Cost breakdown by subsystem is in backup materials

This is projected cost at program end with all reserves projected to be allocated to functions

	FY99	FY00	FY01	FY02	FY03	FY04	FY05	Total
Budget ($M)	11	75	70	17	21	29	20	243
C/S FTE"s	125	133	163	152	114	156	137	979

This chart does not include ESA participation, this will be added later.

X-38 As Built Top Level Cost Analysis

- DDT&E to First Unit Cost ratio is typically between 2:1 and 3:1
  - In X-38 it was 2.57 : 1
  - By this "rule of thumb", the DDT&E cost is reasonable if unit cost is correct
- Working industry metric is $2000/lb of unit cost (flyaway cost) of vehicle for a "lean" aircraft program
  - at 35,000 lbs, this would be a $70 million unit cost
  - X-38 unit cost was 50% more at $125.97M ($3599/lb)
  - unit cost includes all hardware, manufacturing and recurring engineering
  - By this "rule of thumb", X-38 unit cost is reasonable for a new program
- Manpower is typically 2-3 times material
  - In X-38 manpower is 1.3 times the materials cost !
  - this is due partly to the prototyping approach and use of automated tools for design and manufacture
  - this is partly due to the large use of COTS
  - this is also due to the fact that all labor in the manufacturing shops to build parts is charged as material cost when the part is delivered
    - average shop labor on X-38 for the past three years has been 80 people
  - Finally, the deorbit module ($24M), ASE ($1.5M) and a number of other items were delivered as fixed price and therefore considered as material even though there was obviously significant manpower in those elements
    - In CRV estimate we continued to cost the entire items as material

Detailed Cost Breakdown For X-38

- Included in backup materials
- Oriented by 120 WBS Line Items
- Shows yearly spread of expenditures
- Shows breakdown by personnel and materials by year
- Shows breakdown by DDT&E and First Unit Cost
- WBS Line Items are broken down between whether they would be anticipated to be done by the Prime in CRV or remain Nonprime for CRV
  - All work was actually done by NASA, ESA and support contractors
  - NASA was its own prime
  - separating the data this way makes it easier to understand cost basis for CRV later

Comparison Basis - X-38 FY03 Launch As Built To NAFCOM Model

- We ran a NAFCOM cost model to predict the cost of the X-38 space test vehicle in business as usual approaches
- NAFCOM is heavily weight based, with factors for maturity and design reuse. Model run with very low complexity for X-38 systems and a high degree of reuse from other programs
- This was our general approach on X-38 and should not bias NAFCOM to a high answer
- Details of the NAFCOM model are included in the backup material

$M	DDT&E	First Unit	Total Cost	Total Cost as % of NAFCOM Estimate Total Cost
NAFCOM Prediction For X-38 Space Vehicle	1131	337	1467	100 %
X-38 Space Vehicle As Built	319.85	125.97	445.82	30%
X-38 Space Vehicle As Built + All ESA/DLR Contributions	379.85	155.97	536.7	37 %
X-38 Space Vehicle As Built + All Atmospheric Vehicle costs (95-98 – not explicitly included in NAFCOM model) as Space Vehicle DDT&E + ESA/DLR Contributions	494.85	155.97	650.82	44 %

•ESA/DLR contributions are all barter and usually not considered in budget and costs estimates

•Atmospheric vehicle work contains development and test of three prototype vehicles and this content was not explicitly included in the NAFCOM estimate, but could be considered as part of DDT&E underlying the NAFCOM model so it is included for comparison

X-38 As Built To NAFCOM Comparison

WBS Element	Weight	DDT&E FBS Factor	D&D FBS Factor	STH FBS Factor	Make %	X-38 As Built $M	Subsystem % of NAFCOM Model	Subsystem % of As Built X-38	X-38 As Built Percentage of NAFCOM Prediction	Reasons for Differences
GRAND TOTAL	29,773	1			1	536.70			37%	
SYSTEM 1	29,773	1				536.70	100.00	100.00	37%	
HARDWARE TOTAL	29,773		1	1		446.80	60.71	83.25	50%	
Attitude Control System (ACS)	496		1	1	70	5.46	3.03	1.02	12%	Use of COTS and computer models, cold gas simple design
Cold Gas System	496		1	1	50	5.46	3.03	1.02	12%	Use of COTS and computer models, cold gas simple design
Avionics	3,521		1	1	70	96.07	5.55	17.90	118%	Use of COTS and computer aided software engineering
Batteries	1,987		1	1	70	8.40	0.80	1.57	72%	Modified design that has previously flown on shuttle payloads
NiCd	564		1	1	0		0.24	0.00	0%	
NiMH	607		1	1	0		0.25	0.00	0%	
Lithium	816		1	1	0		0.31	0.00	0%	
Communications	115		1	1	70	5.62	0.32	1.05	119%	
Avionics Video	25		1	1	10	0.20	0.05	0.04	25%	Very limited system on X-38 space test vehicle
Avionics Comm	74		1	1	20	3.75	0.23	0.70	110%	NASA Standard Transponder performs most of comm system job
Radar Altimeter	5		1	1	10	0.32	0.01	0.06	320%	
NASA Standard S-Band Transponders	11		1	1	0	1.35	0.03	0.25	338%	Common development with GSFC
Data Handling (incl flt sw)	996		1	1	70	60.25	2.42	11.23	170%	
Computers/Networks/Databuses	240		1	1	0	8.95	1.19	1.67	51%	computer hardware and software. Use of Computer
Avionics Electrical System	742		1	1	50	12.90	1.20	2.40	73%	Use of COTS components and PDS database to define connectivity
Data Recorder	14		1	1	0	0.40	0.03	0.07	100%	
Instrumentation	334		1	1	70	0.65	0.44	0.12	10%	Unmodified COTS
Data Acquisition Units (DAU)	48		1	1	0	0.55	0.31	0.10	12%	Unmodified COTS
Sensors	286		1	1	0	0.10	0.14	0.02	5%	Unmodified COTS
Network Element	31		1	1	50	11.96	0.93	2.23	87%	Based on previous technology effort at LaRC and Draper
SIGI Development	58		1	1	50	9.20	0.63	1.71	99%	Shared costs with STS and ISS, Shuttle and a/c flight testing
Crew Systems	67		1	1	0	0.00	0.00	0.00		
Electro-Mechanical Actuators	1,022		1	1	20	19.50	4.54	3.63	29%	Prototype lessons learned in atmospheric vehicle fed into space vehicle EMA design
Flight Dynamics	41		1	1	70	70.00	0.14	13.04	3333%	NAFCOM is built around satellites. Aerodynamics cost was higher
Air Data Modules	21		1	1	10	1.10	0.07	0.20	100%	Unmodified COTS
Horizon Scanners	20		1	1	10	0.40	0.07	0.07	40%	Unmodified COTS

X-38 As Built to NAFCOM Comparison (cont'd)

WBS Element	Weight	DDT&E FBS Factor	D&D FBS Factor	STH FBS Factor	Make %	X-38 As Built $M	Subsystem % of NAFCOM Model	Subsystem % of As Built X-38	X-38 As Built Percentage of NAFCOM Prediction	Reasons for Differences
GRAND TOTAL	29,773	1				536.70			37%	
SYSTEM 1:	29,773					536.70	100.00	100.00	37%	
Interconnect Wiring	633		1	1	90	11.40	0.44	2.12	175%	USE of PDS database to define and build interconnect wiring
Life Support	1,222		1	1	50	10.30	3.11	1.92	23%	Use of simple techniques for humidity and pressure control, software controls rather than mechanical controls, use of shuttle and ISS heritage parts
Manufacturing	10,148		1	1	70	33.65	4.87	6.31	49%	Use of computer aided design, manufacturing and inspection linked together reduced rework and assembly times
Metallic Structural Parts, Assembly, Manufacturing Planning and Support, Tooling	8,622		1	1	100	26.90	3.28	5.01	57%	
Composite Structural Parts	1,526		1	1	100	6.95	1.47	1.29	32%	
Parafoil	2,901		1	1	70	36.60	27.75	6.82	9%	Use of instrumentation, computer modeling and subscale testing enabled faster progress in full scale drop tests
Winches	167		1	1	0	1.20	0.13	0.22	63%	Modified helicopter winches for space use
Parafoils	1,945		1	1	50	27.20	18.66	5.07	10%	Instrumentation, subscale testing and computer modelling reduced ddt&e
Round Chutes	789		1	1	50	3.20	9.05	0.60	2%	Modified weapons chutes from Sandia
Pyrotechnics	335		1	1	50	3.00	0.16	0.56	125%	Extensive prototyping on atmospheric test vehicles
Structures	5,843		1	1	70	50.01	4.52	9.32	75%	Extensive use of CAD, Reduced part count due to 5 axis machining
Airborne Support Equipment (AS	1,500		1	1	100	1.50	0.07	0.28	136%	
Thermal Protection System	992		1	1	100	4.60	2.70	0.86	12%	application of advanced shuttle technology. Use of CAD and CAM to automate design and manufacture
Fin Mechanism	264		1	1	100	1.10	0.81	0.20	9%	
Secondary Structure	392		1	1	100	2.21	0.63	0.41	24%	
Grapple Fixtures	45		1	1	0	0.40	0.00	0.07		
Pin Retraction Mechanism	326		1	1	100	0.40	0.29	0.07	9%	
ESA CSIC Body Flaps, Nose, etc.	325		1	1	100	70.00	0.00	13.04		
Deorbit Module	3,544		1	1	70	40.60	6.79	7.56	41%	Use of simple monopropellant blowdown system; use of COTS and computer aided design and analysis
Structure	2,951		1	1	100		6.64	0.00	0%	
Propulsion	593		1	1	50		0.15	0.00	0%	
SYSTEM INTEGRATION SUBTOTAL		1			100	89.35	39.29	16.65	16%	Forced more integration into subsystem designers by extending their responsibility over all life cycle phases and by providing computer tools to assist integration (PDS, EMBASSY, CAD)
IACO					1	15.55	1.57	2.90	87%	
STO					1	24.60	4.60	4.58	35%	Use of modern data acquisition and display tools
GSE						15.60	9.71	2.91	11%	
Tooling					1	10.30	1.94	1.92	36%	No Hard Tooling - use soft tooling and laser alignment
M/E GSE					1	5.30	7.77	0.99	5%	
SE&I					1	28.40	11.02	5.29	18%	Use of PDS database to define and build interconnect wiring
PM					1	4.20	10.44	0.78	5%	
LOOS					1	1.00	1.74	0.19	4%	System design personnel responsible through atmospheric testing and on-orbit operations. Supplemented by small cadre of operations personnel
Contingency						0.00	0.00	0.00	#DIV/0!	
Program Support						0.00	0.00	0.00	#DIV/0!	
Fee						0.00	0.00	0.00	#DIV/0!	
FUNCTIONAL RATES (FY2001$)						466.15				
Engineering Labor Hourly Rate: $37.24										
Manufacturing Labor Hourly Rate: $30.66										
Other Labor Hourly Rate: $34.05										
Overhead Rate 135%										

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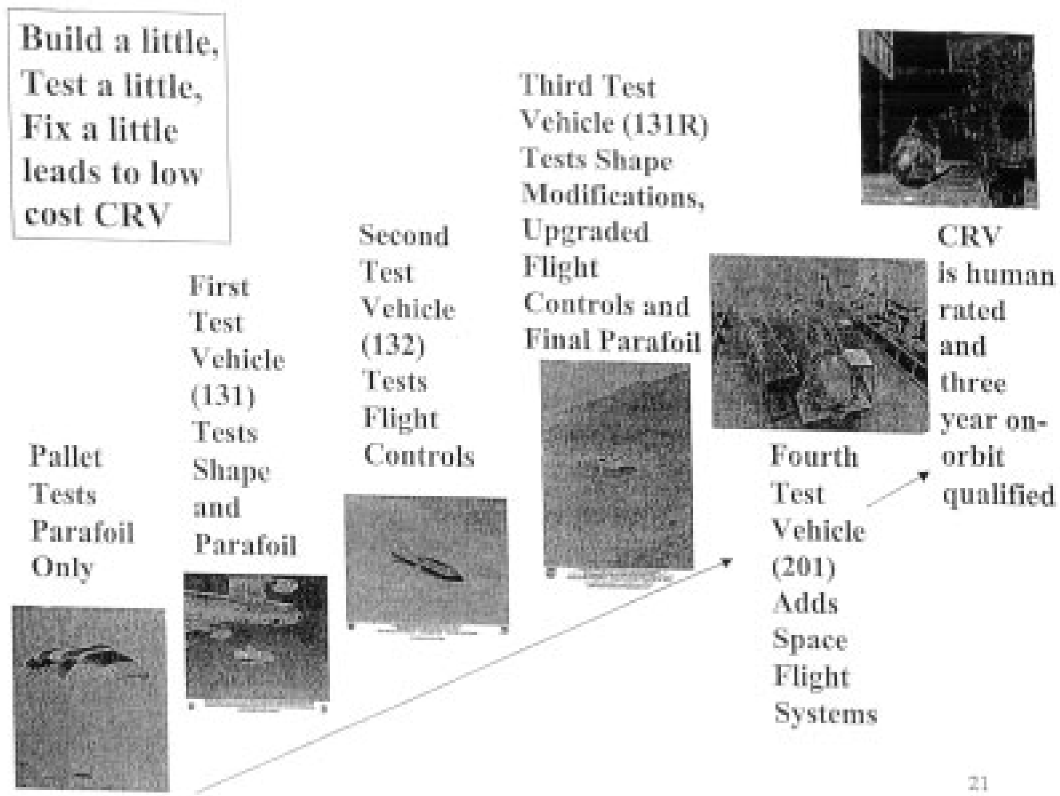
Why were we able to build X-38 for significantly less than NAFCOM prediction

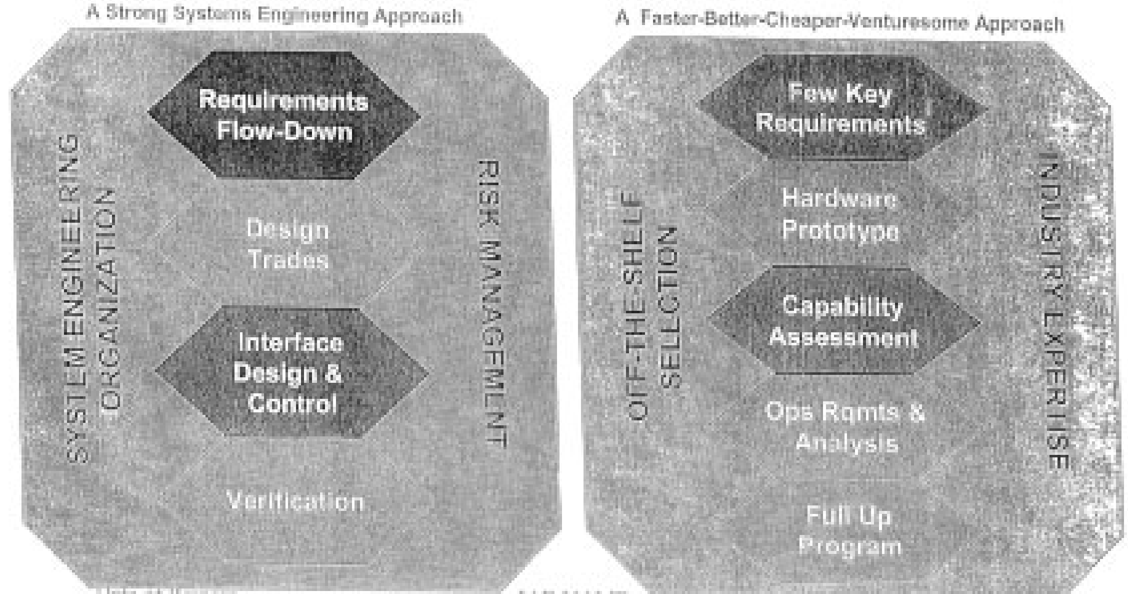
- Our approach is Build a little, Test a little , Fix a little
  - Henry F. Cooper of BMDO calls it Build a little, Test a little, Grow a little
  - JPL calls it Rapid Development Methodology (RDM)
- Rather than trying to mature all elements of the final design simultaneously, concentrate on the key design issues and build and flight test prototypes with available hardware and software to investigate the critical issues
- Avoids having to rework elements of final design that are impacted by the key technology drivers (e.g. parafoil, EMA) but are in themselves not key technology drivers (electrical power distribution, secondary structure, interconnect wiring)
- Working on the prototypes drives out requirement changes that would be costly later in the program
- This is possible because modern technology (flight software tools, composite structures, computer aided design and manufacturing, instrumentation) allows us to rapidly construct and fly low cost prototypes


Build a little,
Test a little,
Fix a little
leads to low
cost CRV
Pallet Tests Parafoil Only
First Test Vehicle (131) Tests Shape and Parafoil
Second Test Vehicle (132) Tests Flight Controls
Third Test Vehicle (131R) Tests Shape Modifications, Upgraded Flight Controls and Final Parafoil
Fourth Test Vehicle (201) Adds Space Flight Systems
CRV is human rated and three year on-orbit qualified
21

Project Management Approaches

STREAMLINED TRADITIONAL — A Strong Systems Engineering Approach

X-38/CRV RAPID PROTOTYPE — A Faster-Better-Cheaper-Venturesome Approach



Date of Review IAR NAME 22

X-38 Original Plan	X-38 Present Evolution
One time experimental test vehicle to demonstrate how human rated vehicles can be built at 1/10th cost	Full Up CRV Prototype
Proven shape	Modified Shape for Expendable Launch Vehicle Compatibility – Majority of effort by ESA
Commercial off the shelf components Parafoil, EMAs, Laser Pyrotechnics, Batteries, Avionics Redundancy Management, INS/GPS Navigation Platform (SIGI)	Parafoil required 5 major design changes, 3 generations of parafoils and 40 full scale tests EMAs required 9 major design changes Laser Pyrotechnics required three generations of design Batteries became custom design Avionics Redundancy Management device became full development effort SIGI required additional development
Peacekeeper Boost Module (ICBM) owned by NASA	Custom stage developed for human rating for deorbit propulsion
CRV requirement – 4 person	Growth to 7 person required structural redesign
CRV Requirement – unpiloted operation	Still requires unpiloted operation, but human rating requires manual backups for ISS separation, on orbit attitude control and parafoil phase of flight
CRV Requirement – Single Fault Tolerant	Dual Fault Tolerance required in critical systems

These changes were worked out in prototype phase (increasing cost of prototype), rather than in full prime development, avoiding much larger cost growth

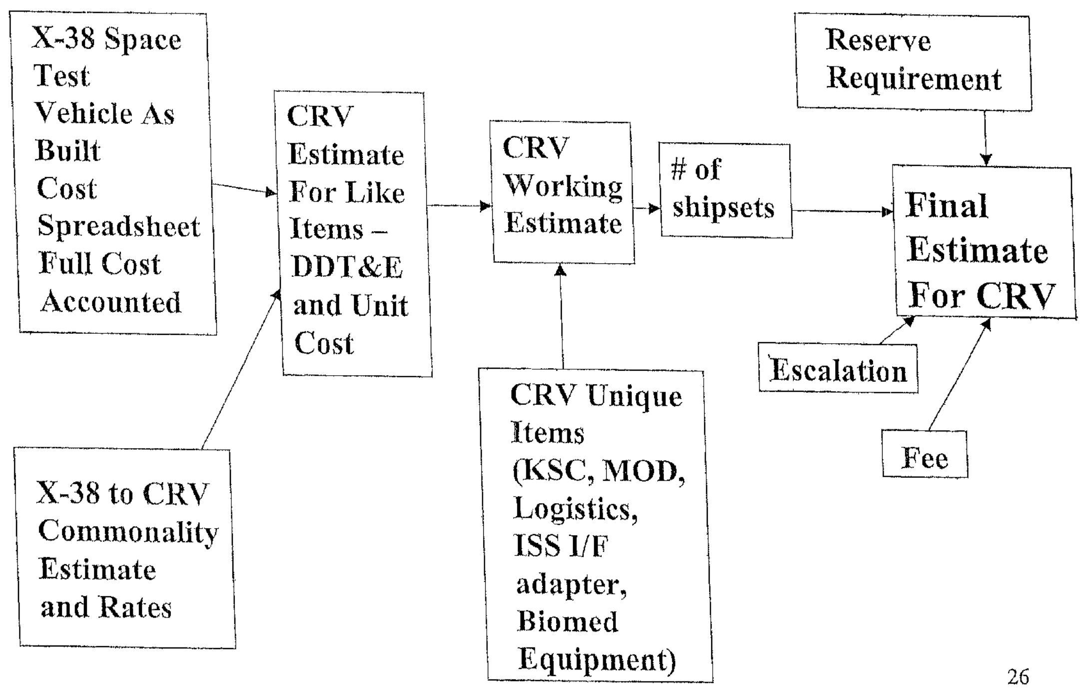
Why were we able to build X-38 for significantly less than NAFCOM prediction - Examples

- We also applied new technologies and available space rated COTS that enabled us to attack problems at lower cost. Examples:
- Instrumentation embedded in parafoil materials, computer simulation and subscale testing took guesswork out of parachute development and allowed us to get more value of large flight tests - Parafoil developed at 9% of NAFCOM model prediction
  - NAFCOM calibrated on Apollo parachute development which was a "cut and try"
  - Apollo human rating was performed 100 development tests DDT&E test and qualified parachutes in 4 tests
  - X-38/CRV will eventually human rate in 80 full scale tests and 400 subscale tests (Double the effort performed to date.)
- Better use of CAD/CAM/CAI - Structure design for 75% of NAFCOM prediction, Manufacturing at 49% of NAFCOM prediction
  - modern design tools allow first time fit avoiding costly rework and shims
  - Impact of 3 axis and 5 axis automatic machining
- Simple design using inhouse design and integration, nontraditional suppliers, and using software controllers rather than complex stand-alone controllers resulted in Life Support System developed at 23% of NAFCOM model cost
- Attitude control system developed at 12% of model predicted cost
  - Cold gas was simpler design
  - impact of use of COTS, computer modeling for system design
  - also all "smarts" in flight software rather than ACS controller hardware
- EMAs developed for 29% of predicted cost
  - Use of simpler EMAs on atmospheric vehicles enabled steep-learning curve

CRV Contract Strategy

- Original plan was for CRV Prime contractor to build four new CRV's based on X-38 design and flight test results
  - this was a $1.255B plan spread over 01-06 with first deployment to ISS in Dec 05
- As part of budget actions from ISS cost issues, we developed a new plan
  - First CRV on ISS will be the X-38 space test vehicle (201) rebuilt into an operational configuration (201R) for deployment on ISS from Aug 2008 – Aug 2011
  - Second and Third CRV will be new production vehicles (301 and 302) built by CRV prime For deployment to ISS from Aug 2011 – Aug 2014
  - this is a $1.4B plan from FY03 through FY11 including NonPrime development, JSC Mission Operations, KSC Operations, Logistics
- This new plan has been technically reviewed by all relevant parties at JSC (Program Office, Engineering, Flight Crew, Mission Operations, SR&QA and JSC Center Director) and has received concurrence

How We Built the CRV Basis of Estimate



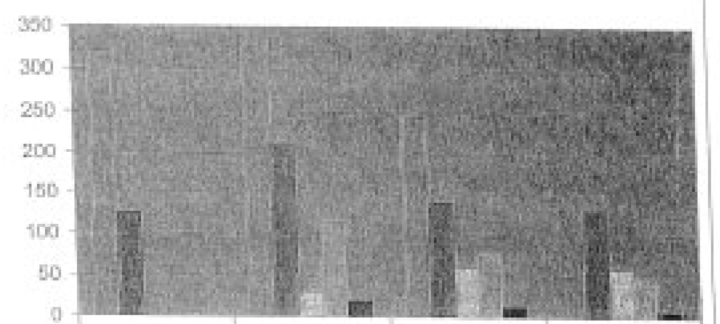
CRV Basis of Estimate Assumptions

- Assumed 200k/FTE in FY02 dollars. This is assumed to be a loaded rate covering all directs and indirect costs (G&A)
- Calculated everything in FY02 dollars and escalated to actual year using OMB/NASA escalation rates (in backup)
- No explicit travel budgeting. Assumed travel costs in loaded rate of $200k/FTE-yr. As a reference point, X-38 has run for the last five years on a $200k/year total travel budget
- No explicit facilities budget. Assumed use of JSC facility for assembly and testing.
  - Use of test facilities (e.g. thermal vacuum chamber) included as budget lines
- Capital equipment replacement was covered in costs of parts. JSC manufacturing funds equipment replacement through fees added to part manufacturing fees.
- Assumed 20% reserve in first time activities and 10% in sustaining engineering vehicle activities.
- Assumed delta development to avoid parts obsolescence for X-38 rebuild and first production vehicle
- Assumed 10% fee on contractor effort for cost plus incentive fee
- Included transportation of vehicles after they are delivered to KSC.
- Assumed ESA will deliver on same parts as they did in X-38. Preliminary agreement on this barter has already been reached.

X-38/CRV Cost by Vehicle

Totals combine Prime and NonPrime costs

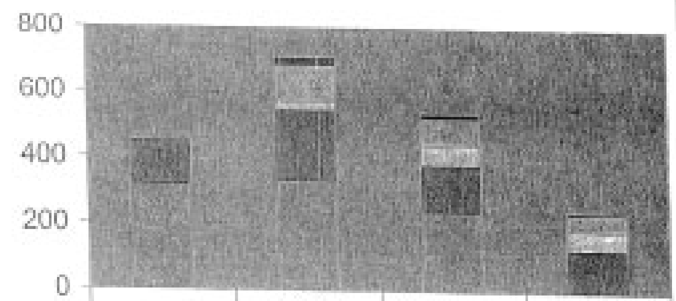
Budget Distribution Across Phases of Project - NASA



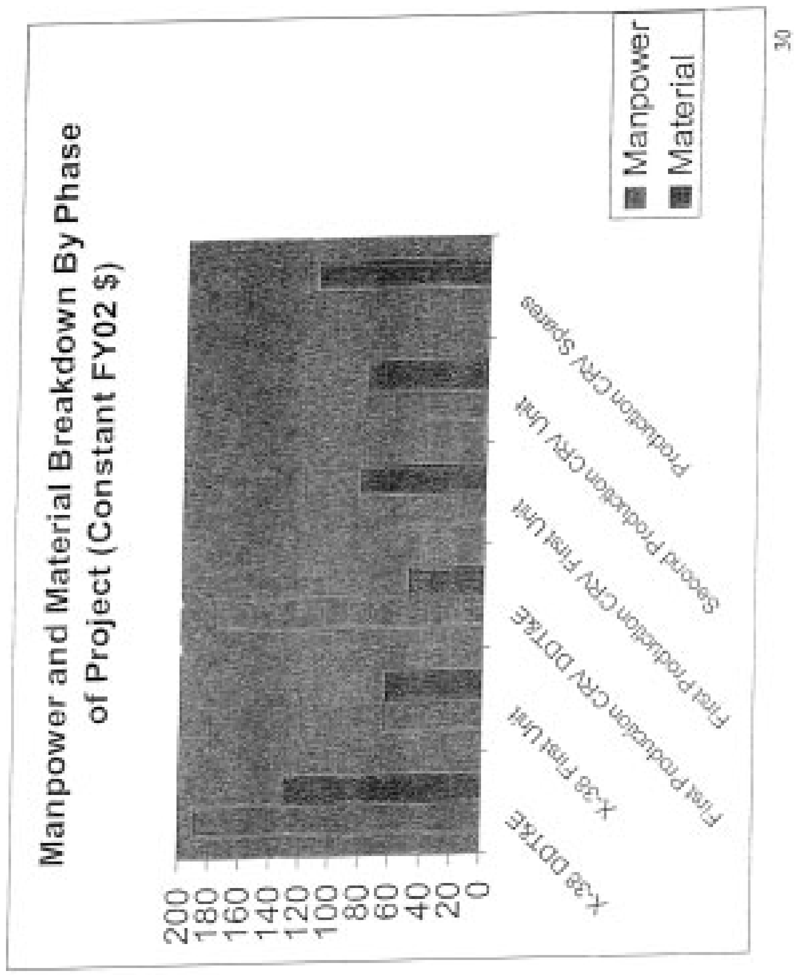
	X-38	X-38 Rebuild Into CRV	First new production CRV	Second new production CRV
DDT&E	319.8	330.73	242.63	
First Unit	126	208.467	139.88	130.815
Spares		29.845	58.885	58.885
Reserve		113.8	79.219	47
Inflation		18.941	13.305	7.9

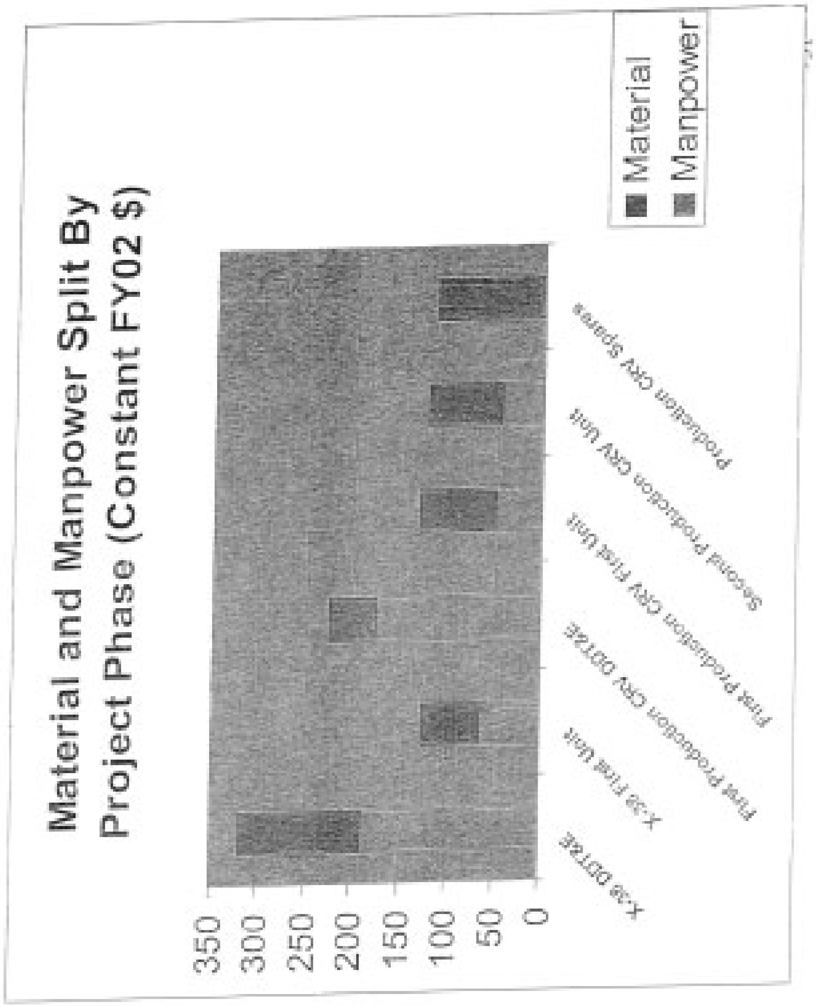
X-38 does not show reserve because this is projected as-built cost and all reserves have been projected into allocations

NASA Budget Distribution Across Phases of Project



	X-38	X-38 Rebuild	First new production	Second new
Inflation		18.941	13.305	7.9
Reserve		113.8	79.219	47
Spares		29.845	58.885	58.885
First Unit	126	208.487	139.88	130.815
DDT&E	319.8	330.73	242.63	


Manpower and Material Breakdown By Phase of Project (Constant FY02 $)
200
180
160
140
120
100
80
60
40
20
0
X-38 DDTkE
X-38 First Unit
First Production CRV DDTkE
First Production CRV First Unit
Second Production CRV Unit
Production CRV Spares
Manpower
Material
30


Material and Manpower Split By
Project Phase (Constant FY02 $)
350
300
250
200
150
100
50
0
X-38 DDT&E
X-38 First Unit
First Production CRV DDT&E
First Production CRV First Unit
Second Production CRV Unit
Production CRV Spares
Material
Manpower

DDT&E Content

- X-38 Rebuild DDT&E content consist of
  - human rating the 201 vehicle
    - add small amount of redundancy – nose jets
    - crew systems and interfaces (window, hatch, hand controllers, displays and controls, couches)
    - additional testing
  - certifying on-orbit capability to three years
    - this is mostly designed in X-38 but hasn't been certified
  - adding the ISS interfaces including the berthing adapter
  - Costs for training simulator and other ops capability development
- Rebuild DDT&E budget is greater than DDT&E for the original X-38
- Rebuild first unit budget is greater than X-38 unit cost
- Rebuild has 20% reserve

- First Production CRV DDT&E content consist of
  - reducing structural weight by 15%
  - improving human interfaces - particularly window and hatch, that cannot be retrofitted into 201
  - upgrading parts for systems that may have become unavailable since 201 was built
- Production CRV DDT&E budget is 73 % of the DDT&E budget for X-38 Rebuild
- Production CRV first unit budget is slightly greater than X-38 unit cost
- First Production CRV has 20% reserve
- Second Production CRV has no DDT&E and unit cost is almost equal to X-38
- Second Production CRV has 20% Reserve

Content – Option to Convert X-38 to first CRV

- Option to convert X-38 to the first CRV contains funding for the following major items
  - X-38 conversion
    - All items identified in the 201 conversion review are budgeted
  - A single deorbit module with delta design for full human rating
  - One full set of subsystem spares (maintained by Prime)
  - The CRV Berthing Adapter (CBA) based on a Boeing PMA
  - Training simulator and mockups
  - Operations capability development (procedures and control center)
  - Medical equipment
  - Prime and nonprime engineering support for KSC support and mission operations for three year on orbit duration
  - Transportation of all flight elements by air between production facilities and KSC
  - All postlanding support is assumed to be provided by host organizations and the JSC Project
  - Human rating and three year on orbit certification for all flight elements
  - A full avionics laboratory for the development and mission support
- Option assumes that the X-38 conversion configuration will be retired at the end of a single 3 year on orbit duration.

Content – Option To Produce Two Addl CRVs

- Option to design and build two production CRVs contains funding for the following major items
  - Design and production activities for two CRV entry vehicles
  - Production of three deorbit modules
  - One full set of subsystem spares (maintained at KSC)
  - Unallocated logistics budget for structiural spares and consumables
  - Storage and periodic checkout of vehicles at KSC
  - Operations capability and training system delta development
  - Medical equipment
  - Prime and nonprime engineering support for KSC support and mission operations through 2012
  - Transportation of all flight elements by air between production facilities and KSC
  - All postlanding support is assumed to be provided by host organizations and the JSC Project
  - A full avionics laboratory for the development and mission support
- Implications of two CRV strategy
  - With two CRVs, one CRV is maintained on-orbit continuously
  - When a vehicle is returned from orbit it must go through a one year refurbishment cycle.
  - This would cause a one year gap where use of the on-orbit CRV could not be immediately replaced by the ground based CRV
  - Crew size would have to be reduced in this contingency to that supported by Soyuz

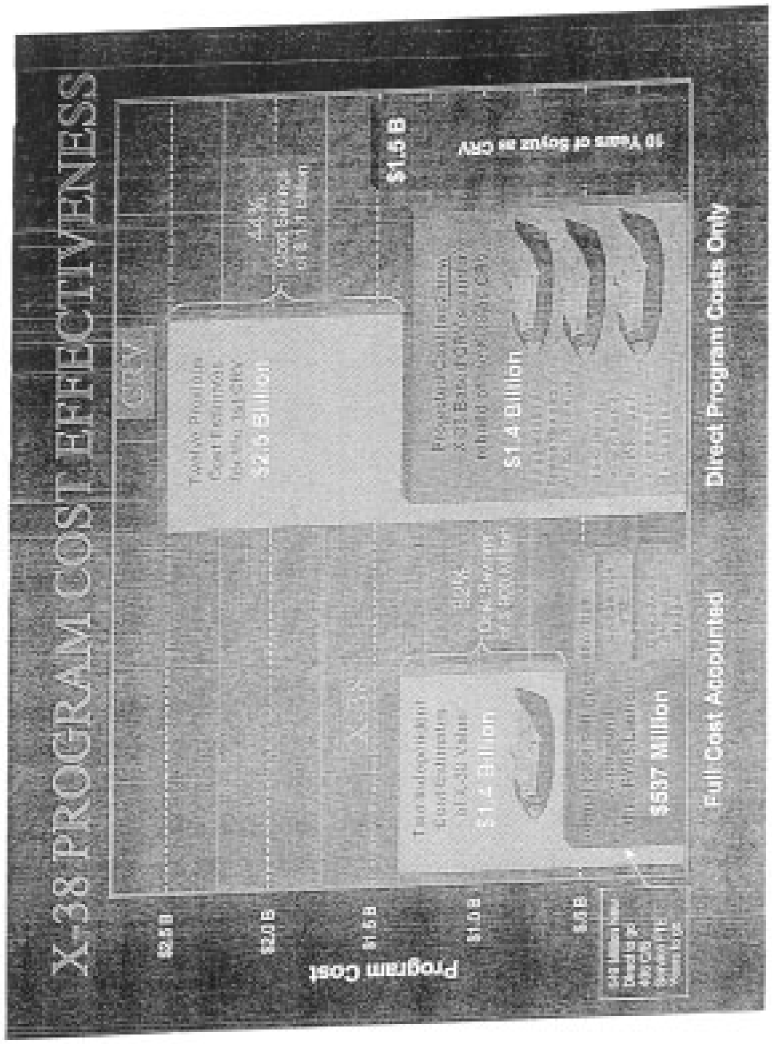
Budget beyond Production Program (2013 and subsequent)

- Sustaining Engineering and Spares at $15M/year (FY02 $)
- Mission Operations at $2M/yr
- KSC at TBD
- Medical Ops at $.5M/yr
- Total per year of $17.5M + KSC
- A refurbishment must be scheduled in 2014 (first CRV) and 2017 (second CRV). Each refurbishment cycle will cost an additional $25M in that year.
  - This would provide support to 2023

Additional Possible Reductions

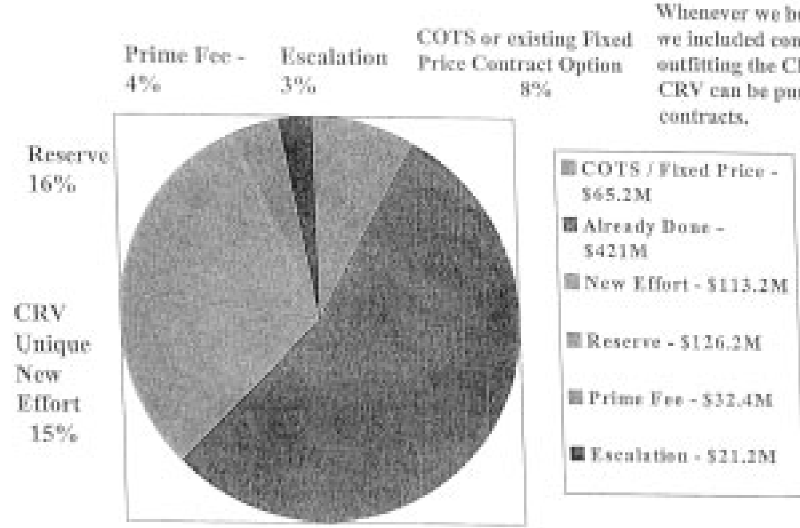
- Increased ESA participation (additional $350M)
- Reuse 201 (X-38) parts as spares for 301($30M)
- If upgrades not required during 301 design ($30M)
- Potential of $410M reduction to lower total bill to $1B
- Minimize redesign from X-38 to first production CRV (TBD)

- We obviously need to get farther into the program before we would take credit for these savings


X-38 PROGRAM COST EFFECTIVENESS
CRV
X-38
Program Cost
$2.5 B
$2.0 B
$1.5 B
$1.0 B
$2.5 Billion
$1.4 Billion
$557 Million
$1.5 B
10 Years of Soyuz as CRV
Full Cost Accounted
Direct Program Costs Only

CRV Content Shows Good Basis of Estimate

Whenever we bought anything on X-38, we included contract options for outfitting the CRV fleet. 8% of the CRV can be purchased on existing contracts.



Effort Already Done Once in X-38 (e.g. structure, wiring, tooling, etc). 54%
Good Basis of Estimate Exists

Reserve is almost as large as estimate for % of new effort

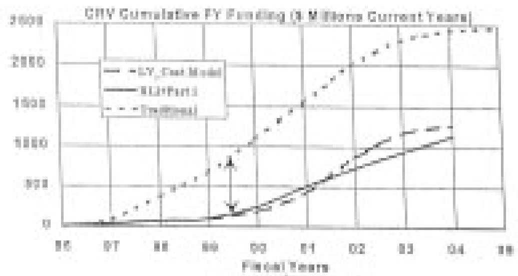
Detailed Cost Breakdown For CRV

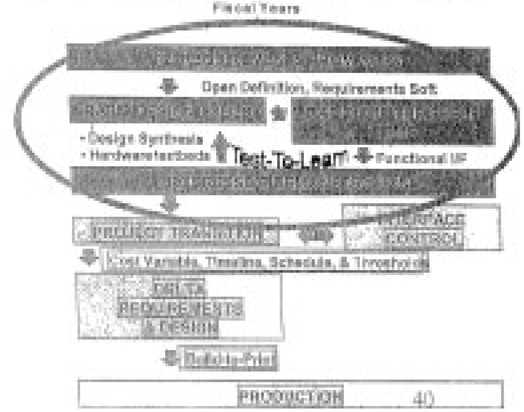
- Included in backup materials
- Oriented by 120 WBS line items
- Shows breakdown by personnel and materials
- Shows Prime and NonPrime split
- Includes details for JSC operations, KSC Operations, Logistics
- Two breakdowns
  - Spread by vehicle shows DDT&E and Unit production cost for 201R, 301, 302 and spares
  - Spread by year shows phasing

X38/CRV Project Credit From the LaRC Independent Assessment Team

- X38/CRV Cost Directive
  - Independent analysis shows favorable results with the BLI
  - Independent analysis shows a traditional project approach would have been considerably more expensive
- X38 produced hardware
  - 12 ACRV traditional type studies produced paper
- X38 successfully handled major mission requirements changes
  - Moved from 4 to 7 person vehicle
  - Traditional approaches would have had set backs

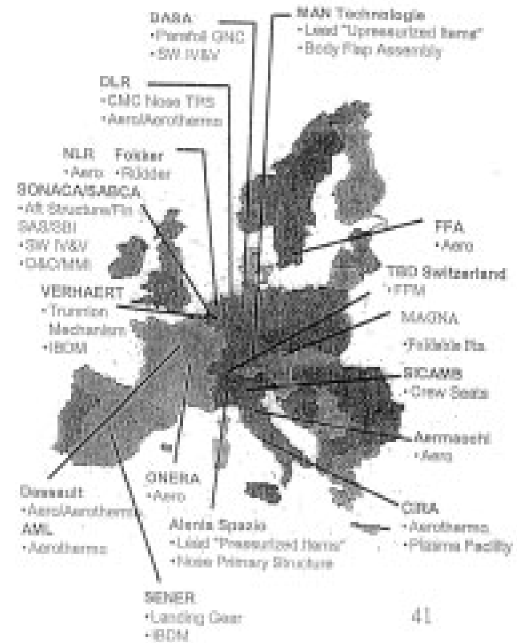
Details of this analysis are in backup materials





Current European Cooperation

- NASA/ESA Protocol on X-38/CRV Cooperation Signed November 1998
- ESA/NASA Agreement on 15 categories of items with value in the range of 100M- $200M
  - final value is still under negotiation
- ESA Subsystems, Assemblies and Equipment to be Provided as GFP to CRV Prime Contractor
- CRV budget assumes ESA delivers on these components



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Potential ESA Cooperation

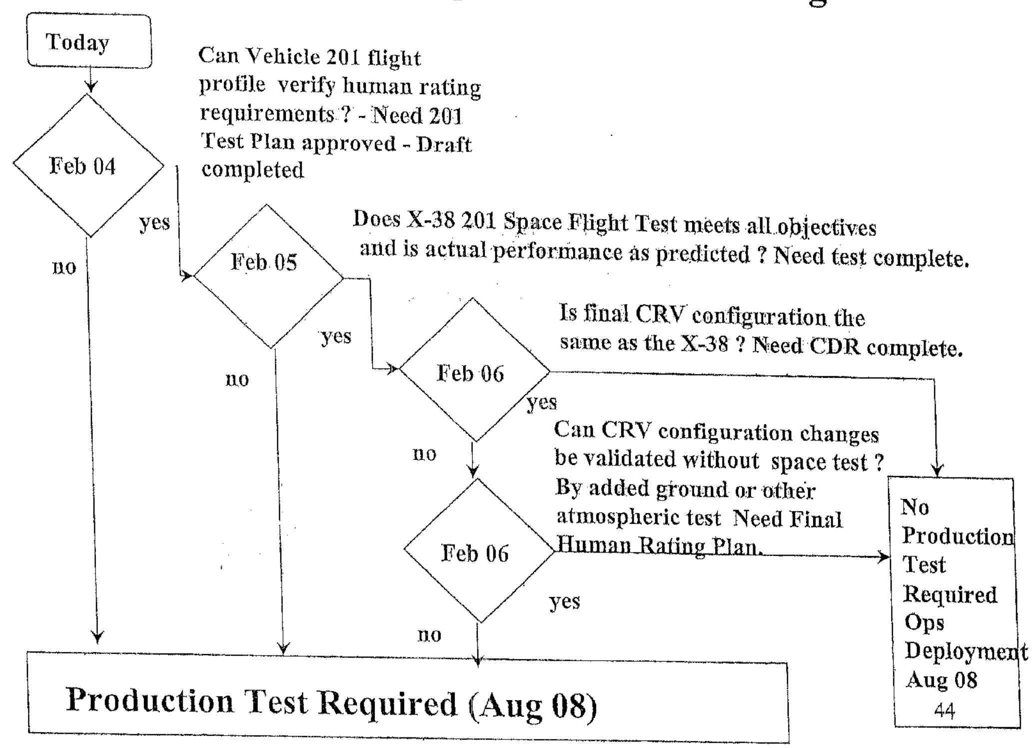
- Summer of 2001 initiated additional discussions for European participation
- Value of such participation might be very large for additional items such as the entire primary structure and some avionics systems
  - CRV prime would receive structure from ESA, outfit ad integrate systems, just as it does when it receives 201R from NASA
  - Prime Bidders concurred with this approach
  - ESA did an outstanding job on X-38 structural components
- ESA discusses this as additional $500M worth of their commitment
- ESA highly motivated to make additional investment to ensure ESA crewmember time on orbit
- ESA funding this additional work by canceling the third Ariane 5/ATV mission and redirecting funds to CRV
  - does not require Ministerial approval, only Program Board
  - NASA has evaluated this and concurs that deleting third Ariane 5/ATV does not compromise logistics for ISS
- This is under discussion with ESA
- CRV budget in this presentation does not assume any of this additional barter occurs
- We will have to evaluate the final negotiation to determine the level of reduction possible in the CRV budget

Risk/Threats

- The top risk/threat to this approach is if the X-38 space test is not sufficient to qualify the CRV for human flight
- This is a controversial issue
- All parties have agreed to a process for deciding whether the space test of the X-38 is sufficient to meet human rating requirements (see next chart)
  - JSC Center Director, Flight Crew Operations, Mission Operations, Engineering, SR&QA and ISS Program have agreed to this process
- The cost risk for an additional flight is approximately $75M
  - plan and execute the test
  - replace expended components (deorbit module)
  - refurbish the vehicle after flight
- This risk is not covered in any reserves
- In addition we would have to find a spot on the shuttle manifest
  - approx $100M to add a flight onto the shuttle manifest if we could not use an existing flight

Decision would have to be made in the Late 05 timeframe, after the X-38 space test

Human Rating Flight Test Decision Logic



Conclusions

- We believe that CRV costs are credible and based on hard data
- Additional ESA cooperation would reduce CRV costs

Enclosure A:
Supplemental material relative to the original Enclosure 3, "November 2002 CRV Cost Estimate By Code BC"

Cost Analysis Division

November 2002 CRV Estimate
Additional Explanation Prepared In Response To House Science Committee Request

- **Code BC estimate assumed same JSC X-38/Crew Return Vehicle definition as contained in JSC April 17 2002 package (the original "Enclosure 2")**
  - Independent Code BC assessment discounted JSC's projections of large inheritance from X-38 and rapid prototyping approach for human rated CRV
  - Included a confidence interval estimate ranging from 30% to 70% confidence levels
  - Other specific assumptions
    - CRV production costs include 3 Units
    - Cost estimates include 30% Contingency, 15% Program Support, and 10% Fee
    - Phasing calculated on 60% cost/50% time curve
    - CRV DDT&E costs spread from FY03 - FY08
    - CRV production costs phased as follows:
      - Unit 1: FY06-FY08
      - Unit 2: FY07-FY09
      - Unit 3: FY09-FY11
    - CRV facilities costs of $2M/yr included in FY07 and FY08
    - Inflation values based on NASA New Start Index
  - Other inputs on following sheets

NAFCOM Cost Model
Technical Inputs Report

Estimate Name:

Prepared By:
Version:

Total Vehicle	33,376.0	*lbs*
Total Stage Weight	33,376.0	*lbs*

CRV System

CRV

CRV Subsystems

Structures & Mechanisms	Est Meth	CG Type*	Weight	STH Qty	% of FU	Make %	Mfg Method	Eng Mgmt	New Design	Test App*	Integ Cmplx*	Pre Dev*	Fund Avail*	Deploy*	Struct Eff		
	CG SA	SC	11,156.0	1	100	70	50	70	45	3	3	2	3	3	54		
Thermal Control	Est Meth	CG Type*	Weight	STH Qty	% of FU	Make %	Mfg Method	Eng Mgmt	New Design	Test App*	Integ Cmplx*	Pre Dev*	Fund Avail*	Act/ Pass*			
	CG SA	SC	3,764.0	1	130	70	75	85	69	3	2	2	3	3			
Environment/Active Thermal Control	Est Meth	CG Type*	Weight	STH Qty	% of FU	Make %	Mfg Metho	Eng Mgmt	New Design	Test App*	Integ Cmplx*	Pre Dev*	Fund Avail*	Act/ Pass*			
	CG SA	SC	975.0	1	100	70	50	50	45	2	2	2	2	2			
Induced Thermal Protection	Est Meth	CG Type*	Weight	STH Qty	% of FU	Make %	Mfg Metho	Eng Mgmt	New Design	Test App*	Integ Cmplx*	Pre Dev*	Fund Avail*	Act/ Pass*			
	CG SA	SC	2,789.0	1	100	70	50	50	45	3	3	2	3	3			
Orbital Maneuvering System	Est Meth	CG Type*	Weight	STH Qty	% of FU	Make %	Mfg Method	Eng Mgmt	New Design	Test App*	Integ Cmplx*	Pre Dev*	Fund Avail*	Enviro*	Reus*		
	CG SA	SC	1,149.0	1	100	70	50	50	45	3	3	2	3	2	2		
Reaction Control Subsystem	Est Meth	CG Type*	Weight	STH Qty	% of FU	Make %	Mfg Method	Eng Mgmt	New Design	Test App*	Integ Cmplx*	Pre Dev*	Fund Avail*	Prop*	ISP	Thrust	Prop Weight
	CG SA	SC	327.0	1	100	70	50	70	45	3	3	2	3	1	280	300	2778
Electrical Power and Distribution	Est Meth	CG Type*	Weight	STH Qty	% of FU	Make %	Mfg Method	Eng Mgmt	New Design	Test App*	Integ Cmplx*	Pre Dev*	Fund Avail*	Power Reg*	Output Power	Stor. Cap.	Design Life
	CG SA	SC	6,566.0	1	100	70	50	70	45	3	3	2	3	1	24000	6000	240
Command, Control & Data Handling	Est Meth	CG Type*	Weight	STH Qty	% of FU	Make %	Mfg Method	Eng Mgmt	New Design	Test App*	Integ Cmplx*	Pre Dev*	Fund Avail*	Redun Rating*	Num Trans.	Freq Bands*	
	CG SA	SC	818.0	1	100	70	50	70	45	3	2	2	3	2	4	3	

Estimate Name:

Prepared By:
Version:

Guidance, Navigation and Control

Est Meth	CG Type*	Weight	STH Qty	% of FU	Make %	Mfg Method	Eng Mgmt	New Design	Test App*	Integ Cmplx*	Pre Dev*	Fund Avail*	Redun Rating*	Stab Method*	Auto*	Comp	Hor. Sens.	Sun Sens.	Rad. Alt.	Star Trckrs.	Gyros	Magnet	Ren. Rad.
CG SA	SC	407.0	1	100	70	50	70	45	3	3	2	3	3	2	4	1	0	0	1	1	1	0	1

Environmental Control and Life Support

Est Meth	CG Type*	Weight	STH Qty	% of FU	Make %	Mfg Method	Eng Mgmt	New Design	Test App*	Integ Cmplx*	Pre Dev*	Fund Avail*	Enviro*	Crew Size	Crew Days
CG SA	SC	2,462.0	1	100	70	50	70	45	3	3	2	3	4	7	17

Crew Accommodations

Est Meth	CG Type*	Weight	STH Qty	% of FU	Make %	Mfg Method	Eng Mgmt	New Design	Test App*	Integ Cmplx*	Pre Dev*	Fund Avail*	Enviro*
CG SA	SC	1,149.0	1	100	70	50	70	45	3	3	2	3	1.2

Recovery and Auxiliary System

Est Meth	CG Type*	Weight	STH Qty	% of FU	Make %	Mfg Method	Eng Mgmt	New Design	Test App*	Integ Cmplx*	Pre Dev*	Fund Avail*
CG SA	SC	3,611.0	1	100	70	50	50	45	3	2	2	1

Landing System

Est Meth	CG Type*	Weight	STH Qty	% of FU	Make %	Mfg Method	Eng Mgmt	New Design	Test App*	Integ Cmplx*	Pre Dev*	Fund Avail*
CG SA	SC	1,967.0	1	100	70	50	70	45	3	3	2	3

CRV System Integration	DDT&	Flt Unit
Integration, Assembly and Checkout (IACO)	0.6	0.6
System Test Operations (STO)	0.6	
Ground Support Equipment (GSE)		
Tooling	0.6	
M/E GSE	0.6	
System Engineering && Integration	0.6	0.6
Program Management	0.6	0.6
LOOS	0.6	
Fee	10 %	
Program Support	15 %	
Contingency	0 %	
Vehicle Level Integration	4 %	

Estimate Name:

Prepared By:
Version:

*Corresponding Text Values For Applicable Inputs

Redundancy Rating (Redun)
1 Not Redundant
2 Partially Redundant
3 Fully Redundant

Stabilization Method (Stab Method)
1 Spin Stabilized
2 3-Axis Stabilized
3 Gravity Gradient
4 Spin/ despin

Deployed (Deploy)
1 No Deployed Structrues
1 No Deployed Structrues
2 One Deployed Structure
3 Multiple Deployed Structures

Power Regulation (Power Reg)
1 Very Little Regulation
2 Moderate Regulation
3 Highly Constrained Regulation

Funding Availability (Fund Avail)
1 Funding Is Assured (No Delays)
2 Some Infrequent Delays Possible
3 Funding is Constrained (Delays Likely)

Pre-Development Study (Pre Dev)
1 Two or More Study Contractors in Phase A&B - Greater than 9 Months of Study
2 One Study Contract - Between 9 and 18 Months of Study
3 Less Than 9 Months of Pre-Phase C/D Study

Integration Complexity (Integ Cmplx)
1 Minimal Major Interfaces involving multiple contractors/centers
2 Moderate Major Interfaces involving multiple contractors/centers
3 Extensive Major Interfaces involving multiple contractors/centers

Reusability (Reus)
1 Reusable
2 Expendable

Active/ Passive (Act/Pass)
1 Passive
2 Active or Active/Passive
3 Thermal Tiles

Test Approach (Test App)
1 Minimum Testing, Qualification Using Simulation and Analysis
2 Moderate Testing, Qualification at Prototype/Protoflight Level
2 Moderate Testing, Qualification at Prototype/Protoflight Level
3 Maximum Testing, Qualification at Component Leve

Environment (Environ)
1 or 1.2 Orbiting Crew Module
1 or 1.2 Orbiting Crew Module
2 or .8 Launch Vehicle Attached Crew Module
3 or 4 Launch Vehicle Crew Cabin

Propulsion Environment (Environ)
1 LOX/RP
2 Launch Only
3 Launch and Orbit

Crew Environment (Environ)
1.2 Launch Environment
.8 Orbiting Laboratory
1.6 Extra Vehicular Environment
2 Lunar or Planetary Surface

Autonomy (Auto)
1 Ground Control
2 Sequencer/ Timed Event
2 Sequencer/ Timed Event
3 Partially Autonomous
4 Fully Autonomous

Propellant (Prop)
1 Hydrazine
2 Hydrogen Peroxide
3 Nitrogen
4 N2H2

Frequency Bands (Freq Bands)
1 1 Band
2 2-3 Bands
3 More than 3 Bands

OMS Environment (Environ)
1 Launch (Launch Only)
2 Launch and Orbit

CG Type
EO:
Earth Orbiting Spacecraft
Earth Orbiting Spacecraft
PSC:
Planetary Spacecraft
Man:
Manned Spacecraft
MLV:
MLV:
Manned Launch Vehicle
ULV:
Unmanned Launch Vehicle
SC:
SC:
Shuttle Calibrated

LRE Propellant (Prop)
LRE Propellant (Prop)
0 LOX/H2
1 LOX/RP-1

LRE Reusability
0 Reusable
1 Expendable

NAFCOM Cost Model
WBS Cost Report
2001 $M

Estimate Name:

Prepared By:
Version:

WBS Element	DDT&&E	D&&D	STH	Flight Unit	Production	Total
CRV System	1,406.9			550.8	1,101.5	2,508.3
CRV	1,406.9			550.8	1,101.5	2,508.3
CRV Subsystems	859.4	527.8	331.4	331.4	662.8	1,522.2
Structures & Mechanisms	271.3	173.3	97.9	97.9	195.8	467.1
Thermal Control	98.9	54.9	43.9	43.9	87.8	186.7
Environment/Active Thermal Control	8.4	6.5	1.9	1.9	3.8	12.2
Induced Thermal Protection	90.5	48.4	42.0	42.0	84.1	174.6
Orbital Maneuvering System	8.8	7.1	1.7	1.7	3.3	12.1
Reaction Control Subsystem	17.2	3.6	13.6	13.6	27.2	44.4
Electrical Power and Distribution	118.0	64.0	54.0	54.0	107.9	225.9
Command, Control & Data Handling	85.4	60.1	25.3	25.3	50.5	135.9
Guidance, Navigation and Control	92.2	68.8	23.4	23.4	46.8	138.9
Environmental Control and Life Support	101.8	60.1	41.7	41.7	83.4	185.2
Crew Accommodations	47.7	21.3	26.3	26.3	52.7	100.3
Recovery and Auxiliary System	8.9	8.3	0.5	0.5	1.0	9.9
Landing System	9.4	6.3	3.1	3.1	6.2	15.7
CRV System Integration	210.1			87.3	174.4	384.5
Integration, Assembly and Checkout (IACO)	42.1			47.1	94.1	136.2
System Test Operations (STO)	61.1					61.1
Ground Support Equipment (GSE)	32.1					32.1
Tooling	6.4					6.4
ME/GSE	25.7					25.7
System Engineering & Integration (SE&&I)	44.9			17.3	34.6	79.5

Shaded areas indicate thruput values

E:\OSP 10_30_02_CRV Only.xls

Estimate Name:

Prepared By:
Version:

WBS Element	*DDT&&E*	*D&&D*	*STH*	*Flight Unit*	*Production*	*Total*
Program Management	29.9			22.9	45.7	75.6
LOOS	0.0					0.0
Fee	106.9			41.9	83.7	190.6
Program Support	176.5			69.1	138.1	314.6
Contingency	0.0			0.0	0.0	0
Vehicle Level Integration	54.1			21.2	42.4	96.5

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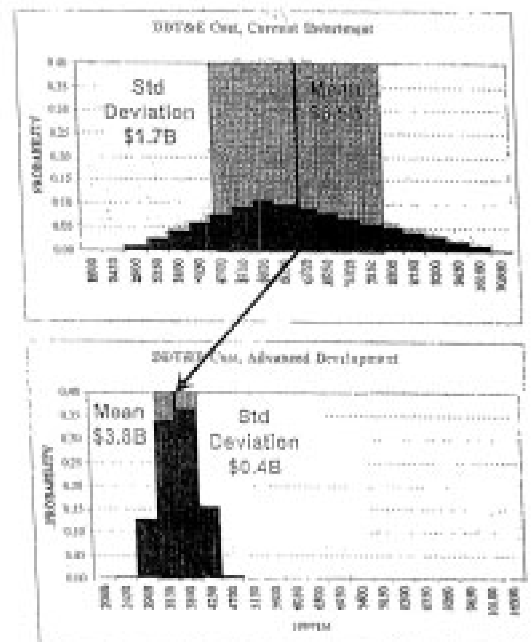
Shaded areas indicate thruput values

Enclosure 4
Original SLI $10 Billion Cost Assumption

Effect of Advanced Development Investment on System Development Cost and Uncertainty

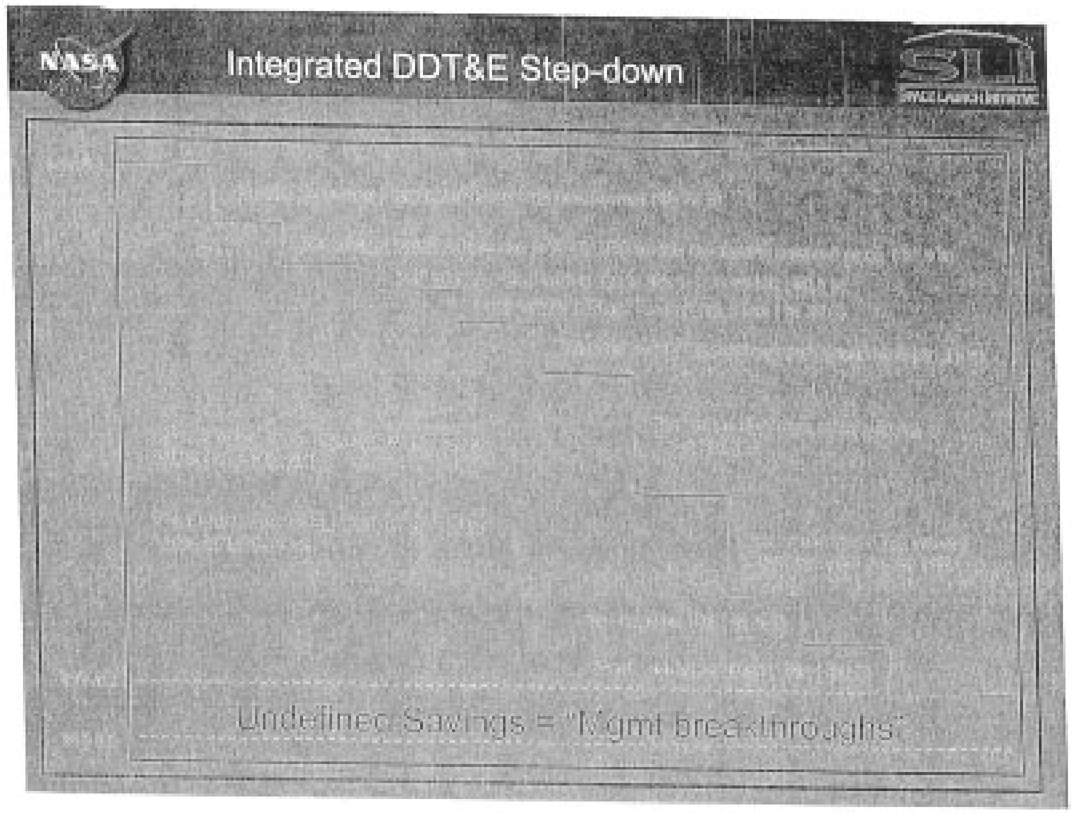
- Current Investment in Space Transportation Technology
  - Development Cost uncertainty range: $3B to $11B
- Increased Investment in Advanced Development, Trailblazers, Ground Test
  - Subsystem, system-level and integration risks retired
  - More experienced team
  - Mature industrial capability
  - Higher design fidelity
  - Resulting Development Cost uncertainty narrowed: $3B to $6B



Enclosure 5
The SLI Program's FY03 Budget Amendment
Estimate of $20 billion

SLI Acquisition Phase Comparison

	[illegible]		[illegible]		[illegible]		[illegible]	
	FY02$B	Qty	FY02$B	Qty	FY02$B (Pess.)	FY02$B (Opt.)	FY02$B (Pess.)	FY02$B (Opt.)
DDT&E	11.814		15.872		26.085	12.845	26.264	12.961
Booster			3.651		10.379	5.690	9.693	4.847
Orbiter			5.874		8.103	3.736	10.149	5.136
PLC			.158				1.693	.781
CTV			4.445		7.603	3.419	4.777	2.298
ISSMM			.158					
Upper Stage			.158					
Spaceport	1.547		1.428					
Production	4.756		7.020		Unit Cost (Pess./Opt.)	Total Cost (Pess./Opt.)	Unit Cost (Pess./Opt.)	Total Cost (Pess./Opt.)
Booster		2	2.249	4	2.524/1.268	5.341/2.683	2.412/1.170	10.207/4.951
Orbiter		3	2.881	4	2.073/0.890	6.580/2.825	2.450/ 1.163	10.369/ 4.879
PLC			.210	4			.432/ .183	1.829/ .774
CTV		4	1.616	2	1.440/.0623	6.094/2.637	.951/ .436	2.076/ .922
ISSMM			.070	2			--	--
Upper Stage		1					--	--
AOTV							--	--
SOTV		1					--	--
Total Acquisition	16.6		22.898			44.10/20.99		50.732/24.477


Integrated DDT&E Step-down
Undefined Savings = "Mgmt breakthroughs"

Enclosure 6

The Four Independent Estimates of SL1

Ranging from ~$30 billion to ~$35 billion

MSFC Space Launch Initiative Cost Credibility Team

Hamaker SLI Acquisition Cost Credibility Study

April 2002

MSFC Space Launch Initiative Cost Credibility Team

Team Members And Support

Core Team

- Paul Componation, University of Alabama Huntsville
- Mel Eisman, Rand Corporation
- Joe Hamaker, MSFC Engineering Cost Office (Team Lead)
- Michael Phipps, NASA MSFC SLI Program Management
- Scotty Scottoline, Consultant, Brandywine Systems
- John Skratt, Principal Director, Space Launch Projects, The Aerospace Corporation
- Darryl Webb, Manager Western Region, Price Systems

Team Advisors

- Bob Lindstrom. Consultant
- Fred Wojtalik, Consultant
- Jean Olivier, Consultant

Team Support

- Team resources: Gene Whitaker, MSFC SMO
- Contractor COTRs: Bob Armstrong, Steve Davis, Charley Dill, Mark Fisher, Pete Rodriguez, Jim Snoddy
- Cost modelers:
  - Ron Hovden, Aerospace Corporation
  - Jeff Murphey, Price Systems LLC
  - Keith Smith & Sharon Winn, SAIC

Background and Team Charter

- **Background: Current SLI cost models based on many space programs but anchored with Shuttle data**
  - Only (partially) reusable space launch system
- **Action assigned by MSFC Center Director Art Stephenson 6 Feb 2002 to MSFC Engineering Cost Office**
  - To form an independent team
  - To survey and understand industry new ways of doing business (NWODB) capabilities since Shuttle
    - With particular attention to new management approaches, technologies, tools and processes
  - Added requirement by SLI: Generate FSD estimated acquisition cost for budgetary planning purposes

MSFC Space Launch Initiative Cost Credibility Team

Study Approach

- Ten aerospace organizations surveyed for NWODB
  - Also included SLI focused technology program
  - Also tabulated Shuttle to SLI architectural puts and takes
- Selected ISAT RP/LH Optimized TSTO RLV with a flyback CTV for assessment purposes
  - Excluded OMV/OTV requirement
- Team translated contractor NWODB and SLI focused technology benefits to cost model
- Utilized 4 cost modelers/models:
  - NAFCOM, PRICE, Aerospace's Launch Vehicle Cost Model and COSTAR
- Major products:
  - Extensive taxonomy of contractor's NWODB with comparisons to Shuttle (not major part of today's brief)

[redacted]

Focus of today's briefing

7

MSFC Space Launch Initiative Cost Credibility Team

Major Ground Rules

- **Cost estimates include**
  - SLI full scale development (FSD) cost from FY '07 forward
    - But only DDT&E, Facilities and Theoretical First Unit
      - Excludes follow on production vehicles, test flights and all ops
  - 15% allowance for subsystem weight growth results in
    - ~ 35% total stage weight increase
      - Translates to ~ 18% cost growth allowance
  - 7% fee, 15% government support
  - No explicit management reserve included—handled by cost uncertainty distributions
- **Range of cost estimates (cost uncertainty distributions) influenced by**
  - Diversity in cost models
  - Application of New Ways of Doing Business (NWODB) vs Business as usual (BAU)
  - Variant assumptions about TRL status at ATP
  - Degree of stage to stage commonality assessed
  - Vehicle design maturity (requirements growth potential)—this very approximately modeled by dry weight variance –10%/+20%
  - Architectural variations—used 120 Study cost spans (but excluded demonstrator)

MSFC Space Launch Initiative Cost Credibility Team

Summary Findings
(Chart 1 of 2)

- Findings on NWODB and the existing SLI cost modeling process
  - Cost models *do account* for general aerospace technology improvements over time
    - General improvements in methods and processes
    - Major engineering tools
    - Major manufacturing tools and processes
  - Cost models *are capable* of adjusting estimates to reflect SLI focused technology improvements
    - In technologies, tools and processes since Shuttle development
      - TRL or design complexities
      - Reduced parts count
      - Deterministic assembly
      - Laser assisted assembly
      - Faster design cycles
      - New design or design legacy
      - Design experience
    - In management approaches
      - Implementation of these are more problematic

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Summary Findings
(Chart 2 of 2)

- **<u>Current</u> modeling exercise preliminary results (for DDT&E + Facilities + TFU):**
  - SLI as unadjusted Shuttle analogy = 10 years, $43 to $48 billion
  - SLI (+/-2 Sigma) with NWODB = 7 years, $28 to $47 billion
    - Wide range results from cost uncertainty assessment regarding a variety of unknowns (see probability distribution charts)
    - $28B represents 35% step down from Shuttle (and $28B includes additional SLI Vehicles/engines)
- **Team concerns:**
  - SLI architecture definition maturity is still conceptual
  - A deterministic cost value is thus unrealistic
  - But a probabilistic range must still envelope very wide variability in project definition, content, success of NWODB initiatives, success of technology program, etc.

Cost Modelers Deterministic Summary Results

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Cost Model Independent Variables

NAFCOM

- General Inputs
  - Funding Availability
  - Risk Management
  - Integration Complexity
  - Pre-Development Study
  - Engineering Management
  - New Design
- Subsystem Specific Inputs
  - Weight
  - Structural Efficiency
  - Output Power
  - Storage Capacity
  - Number of Transmitters
  - ISP
  - Thrust
  - Propellant Weight
  - Propellant Type
  - etc.

PRICE

- General Inputs
  - Specification Level
  - New Design Structures
  - New Design Electronics
  - Design Repeat
  - Integration Factor
  - Engineering Complexity
- Subsystem Specific Inputs
  - Weight
  - Material Type
  - Tolerances
  - Number of Parts
  - %digital/%analog
  - Electronics density
  - Quality of parts
  - Mechanical reliability
  - IC technology
  - etc.

COSTAR

- General Inputs
  - Man-rated vs Non-man-rated
  - Mission type
  - Unit functionality (experimental, demonstrator, full operational)
  - Engineering changes
  - Team experience
- Subsystem Specific Inputs
  - Weight
  - Material type
  - Deployables requirements
  - Thermal control type
  - GN&C sensor type
  - Data rate
  - Engine thrust/weight
  - ISP
  - Thrust
  - etc.

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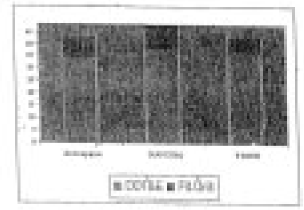
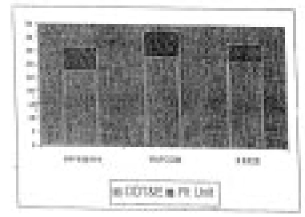
Business As Usual, STS TRL

Vehicle Element	Aerospace	NAFCOM	PRICE
Booster	19,800	19,820	21,455
LOX/RP Engine	1,381	1,359	1,823
Orbiter	16,403	16,706	14,987
LOX/H2 Engine	1,829	1,926	1,854
CTV	3,090	5,766	3,243
Payload Pod	1,123	2,436	1,039
Facilities	2,796	2,796	2,796
TSTO Total	43,272	47,525	43,520



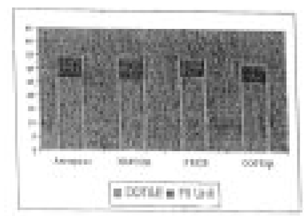
Cost Reduction Initiative, STS TRL

Vehicle Element	Aerospace	NAFCOM	PRICE
Booster	16,614	17,417	18,573
LOX/RP Engine	1,156	1,380	1,670
Orbiter	13,381	14,063	13,109
LOX/H2 Engine	1,468	1,890	1,460
CTV	2,398	5,082	2,747
Payload Pod	922	2,111	939
Facilities	2,796	2,796	2,796
TSTO Total	39,049	42,368	38,152



Cost Reduction Initiative, Tech Program Effects

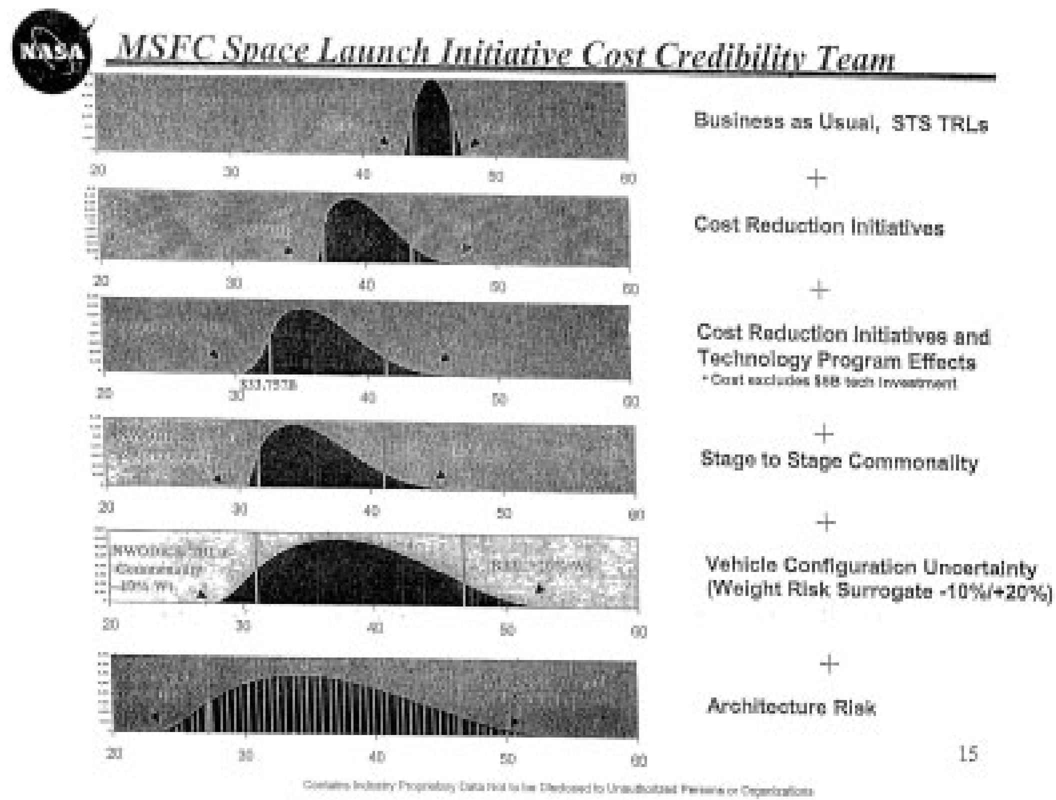
Vehicle Elements	Aerospace	NAFCOM	PRICE	COSTAR
Booster	15,912	13,778	16,223	11,732
LOX/RP Engine	1,105	1,022	1,670	1,606
Orbiter	12,898	11,452	11,588	13,300
LOX/H2 Engine	1,406	1,331	1,485	1,827
CTV	2,146	4,072	2,424	8,094
Payload Pod	839	1,699	692	850
Facilities	2,796	2,796	2,796	2,796
TSTO Total	34,243	33,757	33,722	31,562



Note: Cost includes DDT&E and one Flight Unit

Contains Industry Proprietary Data Not to be Disclosed to Unauthorized Persons or Organizations

Probabilistic Cost Uncertainty Analysis
Summary Results


MSFC Space Launch Initiative Cost Credibility Team
Business as Usual, STS TRLs
+
Cost Reduction Initiatives
+
Cost Reduction Initiatives and Technology Program Effects
* Cost excludes $8B tech investment
+
Stage to Stage Commonality
+
Vehicle Configuration Uncertainty (Weight Risk Surrogate -10%/+20%)
+
Architecture Risk
20
30
40
50
60
15

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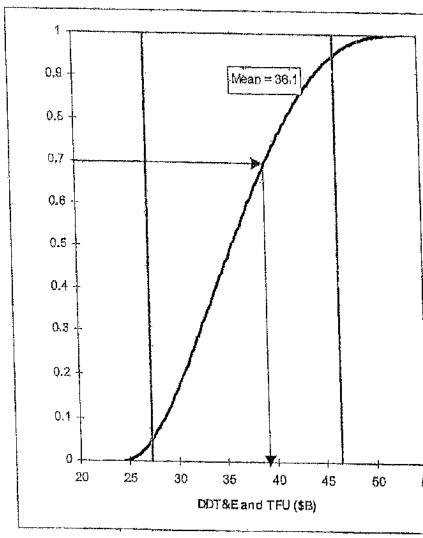
Cumulative Cost Risk Curve

- Included in Risk Curve
  - Modeling uncertainties associated with NWODB initiatives and risk reduction TRLs
  - Vehicle configuration uncertainty
  - Stage commonality
  - Architectural definition
- Excluded from Risk Curve
  - Requirements changes
  - Funding constraints & stability
  - Less than Shuttle team experience
  - Less than TRL 6
  - No demonstrator or OMV
  - Erosion of stage to stage commonality
  - Greater than minimal organizational complexity



Min	24.5
Max	52.9
Mean	36.1
Std Dev	6.9
Mode	34.3
5%	27.3
10%	28.6
15%	29.7
20%	30.6
25%	31.5
30%	32.4
35%	33.2
40%	34.1
45%	34.9
50%	35.7
55%	36.6
60%	37.5
65%	38.4
70%	39.3
75%	40.4
80%	41.5
85%	42.8
90%	44.4
95%	46.5

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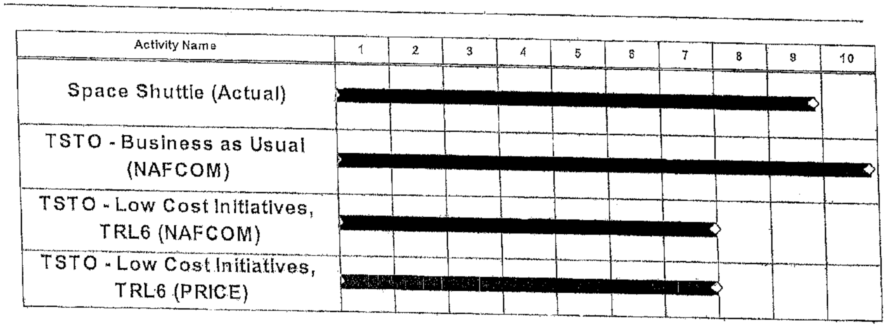
Schedule Estimate Results From Models



Note: Schedules represent deterministic results, not probabilistic

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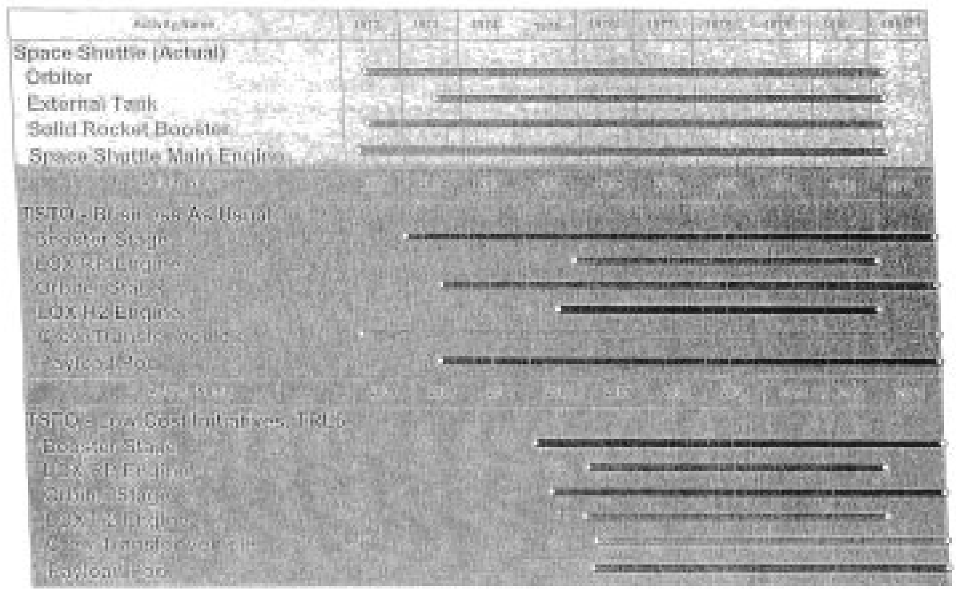
Schedule Estimate Results



Review of Program Cost Threats

- Architecture uncertainty range
- Externally induced requirements changes
- Funding constraints and/or annual funding instability
  - Shuttle was designed to maximum annual funding limit—limited design for operability
- Team experience level possibility less than Shuttle development team
  - Affects cost estimates calibrated to Shuttle
- Technical threats
  - Human rating induced requirements
  - Design maturity , shortfalls in TRL 6, certification spec and operability goals prior to ATP
  - May have to add a demonstrator and OMV to the program
  - Stage to stage commonality
- Organizational complexity (multiple NASA centers, DOD, commercial convergence)
- **Cost estimates do not include the probability of achieving SLI safety, reliability and cost/flight goals other than through vehicle weight and TRL assumptions**
  - Lowest acquisition cost may not result in highest probability of meeting SLI goals

National Aeronautics and
Space Administration

MSFC-RQMT-3360
BASELINE
EFFECTIVE DATE: September 5, 2003

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

UP40

ORBITAL SPACE PLANE (OSP)

LEVEL II SYSTEM REQUIREMENTS DOCUMENT (SRD)

DOCUMENT HISTORY LOG

Status (Baseline/ Revision/ Canceled)	Document Revision	Effective Date	Description
Baseline		09/04/03	Baseline Release

ORBITAL SPACE PLANE
SYSTEM REQUIREMENTS DOCUMENT
SIGNATURE PAGE

Prepared By:

/s/ William A. Jacobs, P.E.	*9-10-2003*
William A. Jacobs, P.E. Requirements Management Office Orbital Space Plane Program	Date

Approved By:

/s/ David C. Leestma	*17 Sept 03*
David C. Leestma Assistant Program Manager Orbital Space Plane Program Office	Date
/s/ Shannon D. Bartell	*9/17/03*
Shannon D. Bartell Assistant Program Manager Orbital Space Plane Program Office	Date
/s/ D. E. Smith	*10 Sept 03*
Dennis E. Smith Manager Orbital Space Plane Program Office	Date

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1 Scope

1.1 Identification

This document establishes the technical requirements for the Orbital Space Plane (OSP) System, hereafter referred to as the OSP, or as the System. The System consists of: a crew rescue capability; a crew transfer capability; and the necessary flight and ground support to perform these capabilities. The spacecraft, for both crew rescue and crew transfer, are to be launched on an Expendable Launch Vehicle (ELV). Programmatic requirements are not captured in this document.

1.2 Document Overview

This document is one in a set of four that documents the NASA Level II technical requirements for the OSP System.

Section 1 of this document contains background information with no direct requirements. Section 2 is reserved for applicable documents that the System must comply with to the extent specified herein. Section 2 may also contain reference documents that are for information only, and that contain no compliance requirements. Section 3 contains System requirements that begin in Section 3.2 (System Characteristics).

Section 4 (Verification) contains definitions of requirements verification methods. Actual verification requirements do not appear in this document, and will be treated in lower level requirements documents.

With few exceptions (if any) this document avoids specifying System features, such as sub-system composition or organization within System elements, or the allocation of System level requirements to System Segments or below.

The relationship of this document to other OSP requirements documents is shown in Figure 1. The documents that represent the OSP Level II Requirements Package as shown in the figure are:

- OSP System Requirements Document (SRD)
- International Space Station Interface Requirements Document (ISS IRD)
- Orbital Space Plane to Expendable Launch Vehicle Interface Definition Document (ELV IDD)
- OSP Human Rating Plan

Additional guidelines contained in NASA program guidance and design standards will be applied to OSP design activities through contracted statements of work. For example, this document contains a high level of detail regarding human acceleration loads since no acceptable NASA standard exists. However, there are additional standards such as those for structural design (e.g., NASA Standard 5001 for factors of safety), which are invoked in the contracts. But the definition of an acceptable human environment is found in NASA Standard 3000 and invoked by the Human Rating Plan. The full development of a government approved, Level III specification will define these requirements to the next level and will reflect full tailoring of all applicable design documents.

NASA does not intend to integrate safety requirements into a single document. The Human Rating Plan specifically addresses Agency-approved requirements for designing safe, human rated systems. Additional safety requirements are addressed throughout the other documents where relevant. Also, the ISS IRD and ELV IDD contain higher fidelity data due to the maturity of those systems. The OSP program's configuration management system will assure full traceability between the documents through a joint Program Control Board with the ISS program.

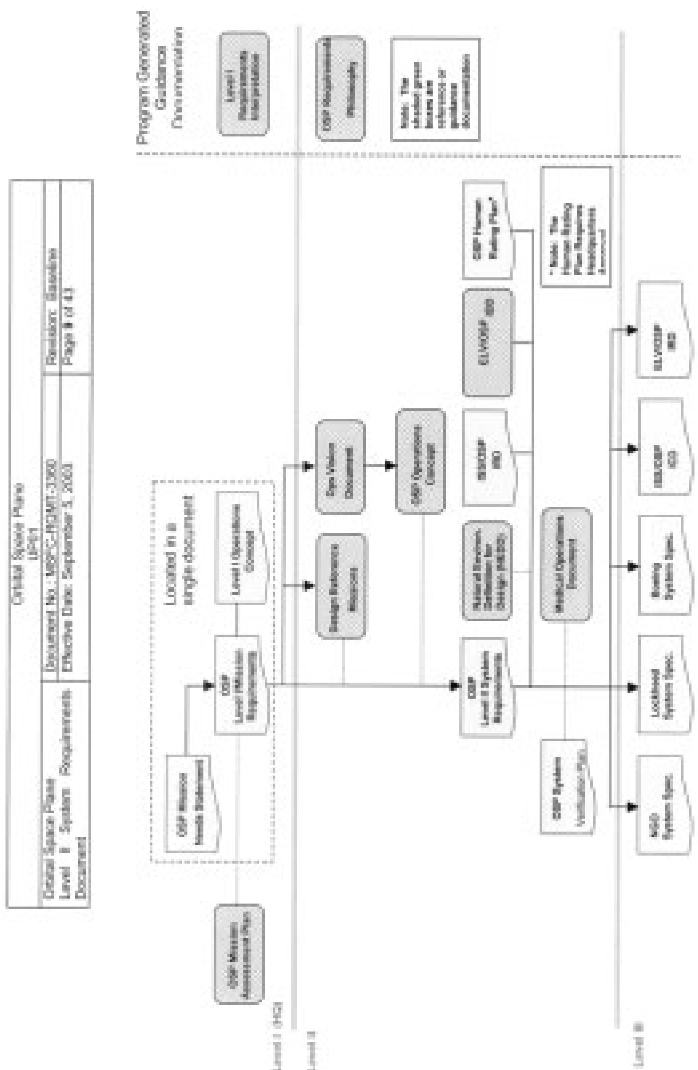

FIGURE 1. OSP Requirements Document Tree

CHECK THE MASTER LIST – VERIFY THAT THIS IS THE CORRECT VERSION BEFORE USE

2 Documents

2.1 Applicable Documents

As stated above, additional guidelines contained in NASA program guidance and design standards will be applied to OSP design activities through contracted statements of work. Applicable documents will be referenced in the SRD only to the extent they can be demonstrated to be essential at Level II for the OSP acquisition. Applicable Documents, to the extent required, are to be cited in the Level III System Specifications generated by the architecture contractors, who will have the contract resources and architecture insight necessary to apply the appropriate tailoring to make the documents suitable for the OSP acquisition.

The following documents form a part of this requirements document to the extent specified herein. In the event of a conflict between the contents of the SRD and the OSP/ISS IRD or a change to the ISS requirements in the SRD, the conflict will be taken to a joint OSP/ISS Board for resolution. In the event a conflict resides between the SRD and the requirements found in the Human Rating Plan (HRP), the HRP will have precedence. In the event of a conflict between other documents referenced herein, or between the applicable documents cited in the Level III System Specification and the contents of this SRD, the contents of the SRD shall be considered superseding. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained. The version of the document applicable will be the latest revision at the time of contract award unless otherwise specified.

2.1.1 Government Documents

OSP-PLAN-022, OSP Program Human Rating Plan (HRP)

SSP 50677, International Space Station Interface Requirements Document (ISS IRD)

LSP-OSPDEV-0001, Orbital Space Plane (OSP) to Expendable Launch Vehicle (ELV) Interface Definition Document (ELV IDD)

OSP-DOC-043, OSP Natural Environment Definition for Design (NEDD)

NSS 1740.14, Guidelines and Assessment Procedures for Limiting Orbital Debris

JSC 27862, Post Mission Disposal of Upper Stages

2.1.2 Non-Government Documents

Reserved.

2.2 Reference Documents

The following documents specified herein are for reference only.

2.2.1 Government Documents

OSP-PLAN-023, OSP Program System Verification Plan (SVP)
OSP-DOC-019, OSP Program Design Reference Missions (DRM)
OSP-DOC-021, OSP Program Operations Concept Document (OCD)
NASA-STD-3000, Man-Systems Integration Standards
NASA-STD-5001, Structural Design and Test Factors of Safety for Space Flight Hardware
JSC 26882, NASA Space Flight Health Requirements
NPG 8705.2, Human Rating Requirements and Guidelines for Space Flight Systems
NPD 8610.7, Launch Services Risk Mitigation Policy for NASA Owned or NASA Sponsored Payloads

2.2.2 Non-Government Documents

Reserved.

3 System Requirements

3.1 System Definition

The following sections provide a general description of the OSP System and a general description of the operational environment. The major external and internal interfaces are also indicated.

3.1.1 System Description

The OSP System will have two primary functions: (1) to provide an ISS crew rescue capability to support either an ISS emergency evacuation or a medical-emergency return of one to at least four de-conditioned crewmembers, one of which may be ill or injured; and (2) to provide an ISS crew transport capability. The rescue capability is to be provided no later than 2010 (with a goal of 2008), and the transport capability no later than 2012. A secondary System function is to carry "contingency cargo" to the ISS on an "as-available" basis. No specific power, thermal, or special environment support is provided for contingency cargo, and the System has no specific ISS cargo supply mission. The generic nature of the ISS crew transport capability may enable other space missions, and it is hoped the System evolves to other capabilities, but no additional specific missions are identified for the OSP. The System flight elements will be launched on Expendable Launch Vehicles (ELVs).

Although the System will consist of segments, the number and definition of those segments is deliberately avoided in this document. The architecture definition, including the structuring of Systems segments, is left as a System developer design freedom. Additionally, the government is leaving the allocation of System requirements among the segments as a System developer design freedom. This is a program level decision, aimed at avoiding the inadvertent favoring of any particular candidate architecture via the definition of segments, or the allocation of requirements among segments.

The OSP's major external interface is with the ISS, for which it supplies crew rescue and crew transport support. Other external interfaces are with systems that provide some measure of support to the OSP. The external interfaces are called out in more detail in Figure 2.

Even though the System segments are not defined or described in this document, two of the System elements are referenced in some requirements. The System will contain a launch vehicle element, which by direction of the Level I Operations Concept will be an expendable launch vehicle (ELV). The System will also contain a flight element that is to be placed into Earth orbit by the launch vehicle element.

3.1.1.1 System Hierarchy

The Systems Engineering process assumes that a system is organized into a hierarchy that helps facilitate the management of system development. OSP is assumed to follow a generally accepted NASA hierarchy:

- System
  - Segments
    - Elements
      - Subsystems
        - Assemblies
          - Subassemblies
            - Parts

The subject and relevance of this document is to the System level. The architecture development contractors will perform the decomposition of System requirements to the segment level and below. The System segment definitions are left as a design freedom for the architecture development contractors. The System Segments are considered the next level of allocation of the requirements below the System level. This allocation will be shown in the Level III System Specification Document.

3.1.2 System Interfaces

3.1.2.1 External Interfaces

The external systems with which the OSP interfaces are identified here. Descriptions of the interfaces, and interface requirements will be treated in separate IRDs for each interface. Precise details of the interface between OSP and each external system will be as negotiated, and agreed to, between OSP and the external systems in an ICD.

Systems with which OSP has external interfaces include:

Range

ISS (& MCC-H)

Federal Aviation Administration (FAA)

External Navigation Systems/TDRSS (gov't-to-gov't interface)

DDMS (gov't-to-gov't interface)

NORAD (Space Object Element Catalog)

Orbital Space Plane UP01		
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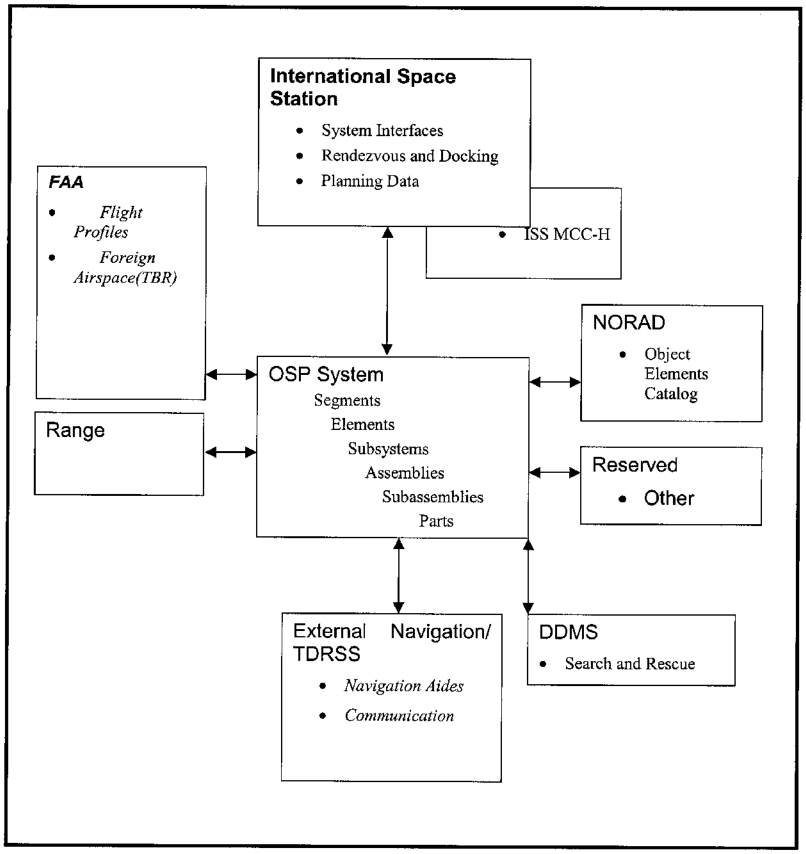

FIGURE 2. System External Interfaces

3.1.2.2 Internal Interfaces

System internal interfaces are not treated in the SRD with the single exception of the interface between System elements and the Launch Vehicle element. An MOU was generated between the OSP Program and the Launch Services Program (LSP) for the acquisition of launch services and the transfer of launch service information to the OSP System. Although the acquisitions are separate, the OSP System contractor will be responsible for the execution of the total system and will develop an Interface Requirements Document between itself and the Launch Services Program. If the allocation of a requirement contains a need for modification to an existing element within the System, this will be brought to the Program Manager's attention for approval and possible negotiations with the Program controlling the element in the System.

3.1.3 Government Furnished Property

To the extent specified in the Statement of Work, the use of existing Government Furnished Property will be assessed for utilization into the OSP Program if it can be shown that doing so will reduce the total Life Cycle Costs of the System.

3.2 System Characteristics.

The System-level functional and performance requirements including safety, loss probabilities, basic missions, System availability, reliability, and similar requirements are captured here.

3.2.1 Performance Characteristics

3.2.1.1 System Launch

Any System ELV will be certified to a Risk Category-3 as defined in NPD 8610.7, Launch Services Risk Mitigation Policy for NASA Owned or NASA Sponsored Payloads.

[SYS0100] The OSP Spacecraft shall be launched on a U.S. ELV.

[SYS0120] The System shall have the capability for the spacecraft to be launched on both the Delta-IV and Atlas-V ELVs.

[SYS0710] The System shall accommodate a stowage capability as late as 16 hours prior to launch.

3.2.1.2 Launch Windows

[SYS0150] The System shall provide the capability to support the next two launch opportunities following a launch scrub.

3.2.1.3 Missions – General

[SYS0190] The System shall be capable of performing all Mission Phases with crew on-board the spacecraft, without crew on-board the spacecraft, and with crew on-board the spacecraft but unable to assist.

3.2.1.4 Maneuverability

[SYS0195] The System shall provide the on-orbit velocity capability to meet all System requirements, including contingency requirements, dispersions, and reserves, plus an additional capability of at least 500 feet per second (152.4 meters per second) of ideal velocity.

3.2.1.5 Emergency Return Missions

[SYS0200] The System shall be capable of returning from one to at least four de-conditioned crewmembers from ISS to Earth, one of which may be ill or injured.

[SYS0205] The System shall have the capability for a crewmember to provide ongoing medical treatment to an ill or injured crewmember during the return phases and to provide the capability to monitor this treatment from the ground.

[SYS0230] The System shall provide rescue capability to return one ill or injured crewmember to definitive medical care within 24 hours from the time that the decision to return has been made and the injured crewmember is ready to be transported.

[SYS0240] The System shall provide the capability to separate from the ISS without ground control support.

[SYS0250] The System spacecraft shall be capable of separating from the ISS at any ISS attitude and up to 2 degrees per second RSS ISS tumble rates and avoid contacting the tumbling ISS.

[SYS0260] The System spacecraft shall be capable of separating from the ISS with a spacecraft crew initiated command.

[SYS0270] In an ISS emergency evacuation condition, the System shall provide crew ingress to the spacecraft and isolation from the ISS within 3 minutes of the decision to evacuate.

[SYS0280] In an emergency condition, the System shall be operationally capable of separation from ISS within 10 minutes of crew ingress and isolation.

[SYS0670] For the rapid separation departure profile (separation maneuvers and deorbit adjustments), the System shall not damage the ISS due to plume impingement.

[SYS0672] For the rapid separation departure profile (separation maneuvers and deorbit adjustments), the resulting trajectory shall avoid contact with ISS and other visiting vehicles.

[SYS0290] The System shall leave the ISS mating port available and ready for mating after separation from ISS.

3.2.1.6 Crew Transfer Missions

[SYS0300] The System shall transfer any combination of one to at least four crewmembers from Earth to the ISS and back.

3.2.1.7 Mission Frequency

[SYS0400] The System shall be capable of providing, on average, one emergency return mission every four years for the operational life of the system.

[SYS0410] The System shall have the capability to provide at least four roundtrip crew transfers per year for the operational life of the System.

3.2.1.8 On-orbit Mission Duration

[SYS0520] The System shall provide a capability to rendezvous and mate with ISS within three days of launch for the Earth-to-ISS portion of the crew transfer mission.

[SYS0525] The System shall have sufficient resources to allow 2 days of contingency operations by the spacecraft while not mated to the ISS.

3.2.1.9 Contingency Cargo Requirements

[SYS0550] The System shall have the capability to transfer contingency cargo in lieu of some or all of its crewmembers from Earth to the ISS and back.

3.2.1.9.1 Contingency Cargo Support

[SYS0700] The System shall provide the capability for the receipt, processing, integration, and de-integration of contingency cargo.

3.2.1.10 ISS Operations

[SYS0603] The OSP system shall provide the capability to mate and ingress an unoccupied ISS.

[SYS0605] The System shall mate to the port and starboard Node 3 Port on the US portion of the ISS.

[SYS0606] The System spacecraft shall be capable of supporting the crew rescue mission (long term stay) on both the Node 3 Port and Starboard locations without requiring swapping ports.

[SYS0608] The System spacecraft shall provide sufficient margins, including consumables, for a minimum of two approach and mating attempts from an operationally safe standoff distance to the ISS.

[SYS1631] The System shall have the capability to simultaneously support operations with two spacecraft mated to ISS for a minimum of 7 days.

[SYS0680] Following a declaration of emergency, the System shall provide for crew rescue without any assistance from ISS with the exception of structural provisions.

[SYS0685] The System shall have the capability to remain attached to ISS with nominal attitude control, for a minimum of 12 hours while isolated from ISS resources, with up to 4 crew onboard using contingency day consumables.

[SYS0687] The System Spacecraft for crew rescue shall, when mated to the ISS, have a minimum on-orbit functional life of 9 months.

3.2.1.11 Acceleration Environment

[SYS0812] The System induced g-loads on the crew shall not exceed the limits defined in Figures 3, 4, and 5. The coordinate system is depicted in Figure 6.

[SYS0814] The maximum rotary accelerations imposed on crewmembers by the System during all mission phases shall comply with human performance and tolerance limitations for de-conditioned and ill or injured individuals, Figures 7.

Orbital Space Plane UP01		
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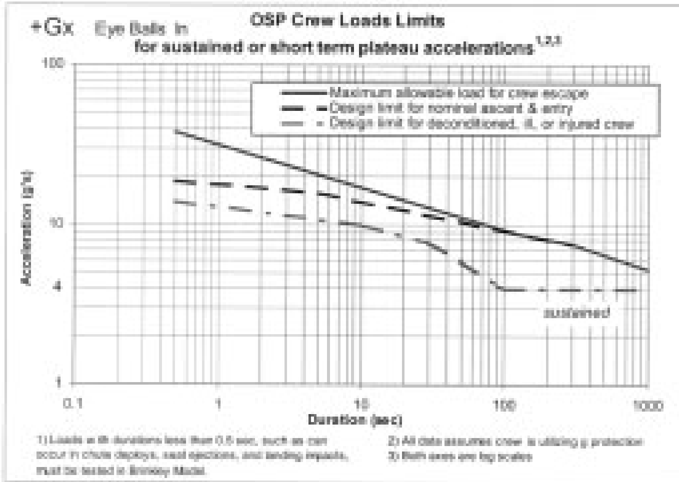

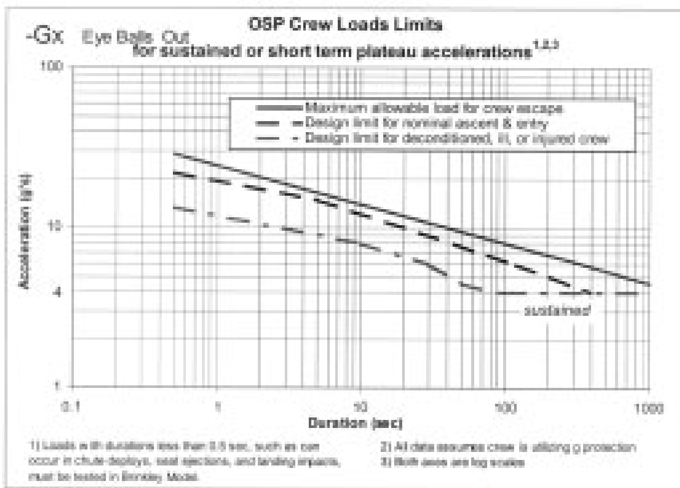

FIGURE 3. Crew Loads Limits X

Orbital Space Plane UP01		
Orbital Space Plane Level II System Requirements Document	Document No.: MSFC-RQMT-3360	Revision: Baseline
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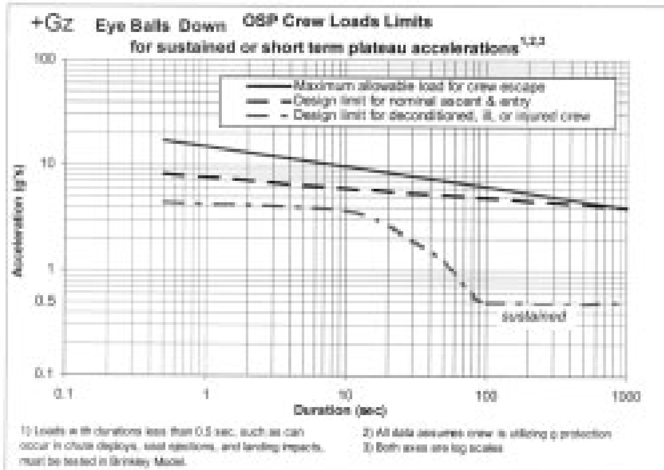

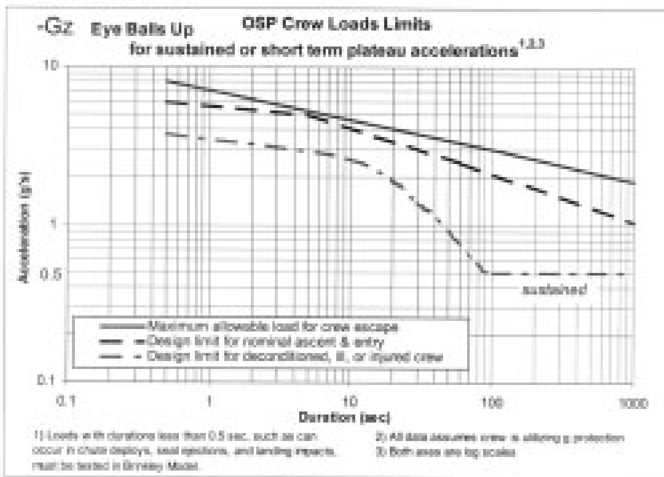

FIGURE 4. Crew Loads Limits Z

Orbital Space Plane UP01		
Orbital Space Plane	Document No.: MSFC-RQMT-3260	Revision: Baseline
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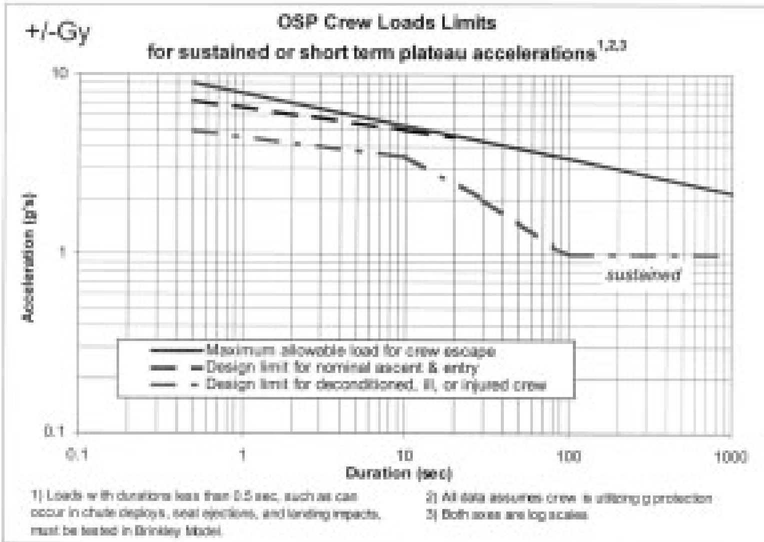

FIGURE 5. Crew Loads Limits Y

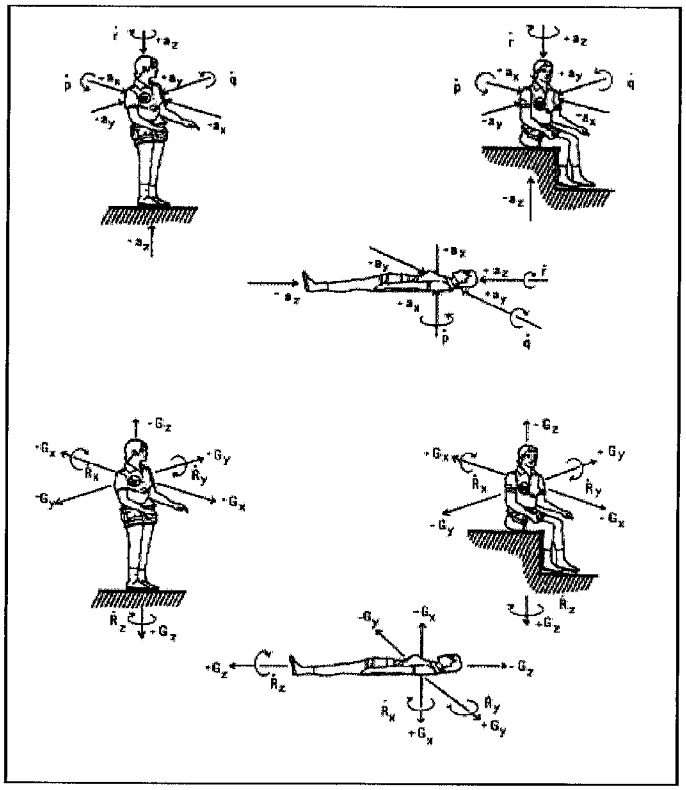

FIGURE 6. Acceleration Environment Coordinate System Used in NASA-STD-3000

Page 1 of 2

Linear Motion	Direction of Acceleration		Inertial Resultant of Body Acceleration	
	Acting Force	Acceleration Description	Reaction Force	Verticular Description
Forward	$+ a_x$	Forward accel.	$+ G_x$	Eye Balls In
Backward	$- a_x$	Backward accel.	$- G_x$	Eye Balls Out
Upward	$- a_z$	Headward accel	$+ G_z$	Eye Balls Down
Downward	$+ a_z$	Footward accel.	$- G_z$	Eye Balls Up
To Right	$+ a_y$	R. Lateral accel.	$+ G_y$	Eye Balls Left
To Left	$- a_y$	R. Lateral accel.	$- G_y$	Eye Balls Right
Angular Motion				
Roll Right	+ p&		$-$ R&$_x$	Cartwheel
Roll Left	− p&		+ R&$_x$	
Pitch Up	+ q&		− R&$_y$	Somersault
Pitch Down	− q&		+ R&$_y$	
Yaw Right	+ r&		+ R&$_z$	Pirouette
Yaw Left	− r&		− R&$_y$	

FOOTNOTES:

Large letter, G, used as unit to express inertial resultant to whole body acceleration in multiples of the magnitude of the acceleration of gravity.

Acceleration of gravity, $g_z = -$ 980,665 cm/sec^2 or 32.1739 ft/sec^2.

FIGURE 6. Acceleration Environment Coordinate System Used in NASA-STD-3000

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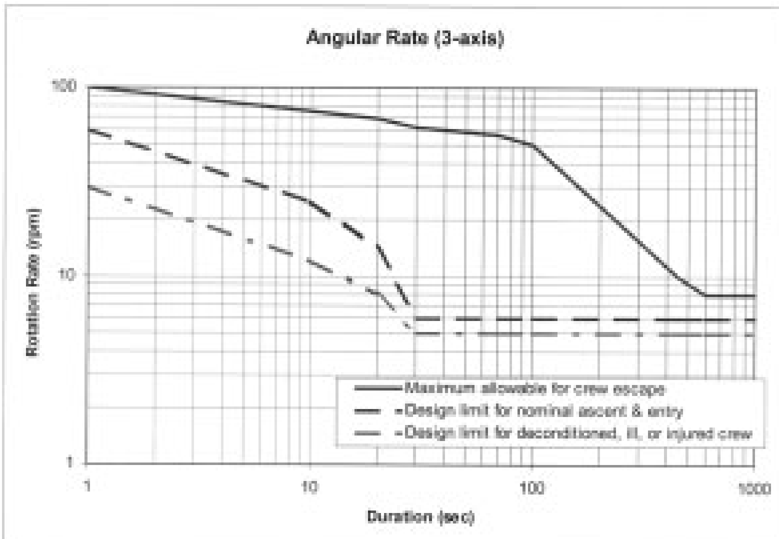

FIGURE 7. Rotational Acceleration

3.2.1.12 Health and Status

[SYS0930] The System shall provide the capability to record health and status data.

[SYS0980] The System shall not require crew interaction for routine monitoring of the spacecraft during nominal operation.

[SYS1620] The System shall annunciate status alerts.

[SYS1630] The System shall have a survivable flight data recorder for instances of abort or escape.

[SYS1640] The System shall have the capability to use the health and status data to reconfigure systems to recover functionality.

[SYS1650] The System shall provide the capability to transmit mission critical recorded health and status data to the control center(s) during mission operations.

3.2.1.13 Communications

[SYS1120] The System shall provide full-duplex voice communication between the supporting control center(s) and the spacecraft crew.

[SYS1140] The System shall provide a minimum of 75% communications capability per orbit between the spacecraft and the control centers while not mated to ISS.

[SYS1170] The System spacecraft shall have the capability to accept ground updates and provide verification that updates were accurately received.

3.2.1.13.1 Video

[SYS1220] The system shall provide the capability to obtain and transmit images and video.

3.2.1.14 Crew Environment

[SYS1400] The System shall provide a habitable environment to support crew performance.

[SYS1430] The System shall provide life support and a safe post-landing environment for the crew through crew recovery.

3.2.1.15 Mission Planning

[SYS1500] The System shall provide the capability to perform mission planning.

[SYS1510] The System shall provide the capability to remove time critical items within 1 hour of crew recovery or spacecraft recovery where no crew is present.

[SYS2570] The System shall provide the capability for post mission recovery of crew and spacecraft.

3.2.1.16 Mission Control

[SYS1600] The System shall provide the capability to perform mission control.

[SYS1610] The System shall have the capability to command the spacecraft from the ground.

3.2.2 System Location Constraints

This section sets forth requirements, which establish boundary conditions, and constraints necessary to assure physical compatibility and which are not defined by interface requirements.

[SYS1800] The System shall be based within the United States, or within territory controlled by the United States.

[SYS1810] For nominal return missions, the System shall land flight vehicles within the United States, or recovery sites that comply with the International Traffic in Arms Regulations (ITAR).

3.2.3 Reliability, Maintainability and Supportability (RMS)

3.2.3.1 Reliability

[SYS1910] For crew rescue, the System shall provide a per mission probability of loss of crew (LOC) of 1/800 or less with 50% confidence, with an objective of 1/800 or less with 80% confidence.

[SYS1920] For crew transfer, the System shall provide a per mission probability of loss of crew (LOC) of 1/400 or less with 50% confidence, with an objective of 1/400 or less with 80% confidence.

[SYS2800] The probability of loss of life to the ground crew attributable to the System shall be less than 300×10^{-6} per mission.

[SYS2810] The probability of loss of life to the general population attributable to the System shall be less than 30×10^{-6} per mission.

3.2.3.2 Maintainability

[SYS2001] The System spacecraft shall require no scheduled maintenance during unmated flight operations.

[SYS2020] The System shall provide for on-orbit maintenance of internal ORUs compatible with ISS on-orbit tools.

[SYS2100] For a nominal mission flow, the System (exclusive of the ELV delivery) shall perform mission preparation and ground processing in less than 60 workdays per flight, with a goal of 45 workdays per flight.

[SYS2120] The System shall be maintained, while mated to the ISS, utilizing corrective, in situ, or preventive maintenance.

3.2.3.3 System Availability

[SYS2302] The System Crew Rescue availability, once the OSP rescue spacecraft is mated to the ISS, shall be at least 0.95 with 50% confidence with an objective of 0.95 with 90% confidence.

[SYS2310] While mated to ISS, the System shall maintain availability during ISS resource outages for periods of at least 24 hours from a steady state condition.

3.2.3.4 Launch Probability

[SYS0130] The System shall have a launch probability greater than 75% due to weather constraints affecting the launch site and control center(s).

[SYS0131] The System shall have a launch probability greater than 95% due to weather constraints affecting the abort landing site(s).

[SYS0132] The System, exclusive of ELV and weather constraints, shall have a launch probability greater than 85%.

3.2.3.5 System Lifetime

[SYS2400] The System shall have an operational life thru at least 2020, but not less than 10 years from the Initial Capability.

3.2.4 System Safety

3.2.4.1 General Safety

[SYS2500] No single System failure (excluding items that are designed for minimum risk) or single human error shall result in a critical hazard or catastrophic hazard. Catastrophic hazards that lead to loss of life or permanent disability are addressed in [HRR 500].

[SYS2540] Subsystems or components of the System performing safety critical functions shall be physically separated, isolated, or protected such that any credible event does not result in the loss of more than one hazard control.

[SYS2590] The System software/firmware performing, controlling, or supporting safety critical functions shall be isolated or protected such that any failure of non-critical software/firmware does not affect the performance of the critical software/firmware.

[SYS2820] The System shall meet the requirements of, Human Rating Requirements and Guidelines for Space Flight Systems, NPG 8705.2, as tailored for the OSP Program and documented in section 4.0 of the OSP Human Rating Plan, "OSP-PLAN-022".

[SYS3500] The System shall be designed to eliminate or control catastrophic and critical hazards by employing the Hazard Reduction Protocol techniques listed below in order of precedence:
Protocol 1: Design to eliminate hazards.
Protocol 2: Where the design cannot eliminate hazards, control hazards through design features such as failure tolerance;
Protocol 3: where design for fault tolerance is not practical, control hazards through 'design for minimum risk'.
Protocol 4: Employ safety devices to reduce hazards that cannot be eliminated by design, or controlled by design features.
Protocol 5: Employ warning devices, training or special procedures to reduce the risk associated with hazards that cannot be eliminated or controlled.
Protocol 6: Employ emergency functions, such as crew escape, where Protocols 1 through 5 are not adequate to reduce hazards to acceptable levels.

3.2.4.2 Crewed Vehicle Safety

[SYS2730] The System Spacecraft shall successfully complete its mission without requiring an EVA.

3.2.5 Environmental Conditions

[SYS2900] The System shall meet all requirements specified herein when exposed to the environments as described in the Natural Environments Definition for Design (NEDD), OSP-DOC-043.

[SYS2910] The System shall meet the requirements specified in this SRD during and after the full range of induced, including self-induced, environments encountered during System operations.

3.2.6 Transportability

[SYS2950] The System elements shall be transportable to their operational locations.

3.2.7 System Disposal

Reserved.

3.2.8 System Security

3.2.8.1 Mission and Physical Security

Security risk assessments will be conducted for each mission and include analysis of any terrorism related threats and an analysis of any security risks. In the event a mission or cargo is classified, applicable federal regulations will apply.

[SYS3000] The System shall provide security measures to prevent inadvertent or unauthorized commanding or modification of data by using National Security Agency recommended encryption in protecting command links.

[SYS3050] The System and associated personnel shall be guarded and protected against willful damage, unauthorized access, sabotage, or theft.

3.2.8.2 Information Technology Security

[SYS3100] The System shall provide information technology security.

3.2.9 System Interface Requirements

3.2.9.1 External Interface Requirements

[SYS3200] The System interface with the ISS shall meet the requirements prescribed in SSP50677, ISS to OSP Interface Requirements Document.

[SYS3210] The System shall have an interface with supporting external navigation systems.

[SYS3230] The System shall have an interface with the FAA.

[SYS3240] The System shall interface with its launch range.

[SYS3250] The System shall have an interface to Department of Defense Manned Space Flight Support (DDMS) (gov't-to-gov't interface) to support OSP search and rescue contingencies.

[SYS3260] The System shall have interfaces with the Tracking and Data Relay Satellite System ground and space networks.

[SYS3274] The System shall have an interface with the NORAD providers of the space object element catalog.

3.2.9.2 Internal Interface Requirements

The System interface with its associated ELV system is described in the Orbital Space Plane (OSP) to Expendable Launch Vehicle (ELV) Interface Definition Document (IDD), LSP-OSPDEV-0001.

3.2.10 Ground Support Equipment

[SYS3400] The System shall provide the capability to prepare the flight crew at the launch site.

[SYS3410] Any System-provided ground support equipment shall be designed and certified for use at its intended operational locations.

[SYS3420] The System shall provide facilities and ground support equipment that are compatible with flight systems, ground systems, and other equipment utilized for ground operations to preclude degradation or contamination of flight hardware.

3.3 Design and Construction Standards

3.3.1 Human Engineering/Human Performance

[SYS3990] The System shall provide work and habitable space, access, stowage and physical accommodation in the defined use environments and for the defined tasks.

[SYS4010] The System shall require a crew awake period less than 18 hours for the first flight day.

[SYS4020] The System shall accommodate Launch and Entry Suited (LES) and non-suited crewmembers.

3.4 Computer Resource Requirements

Reserved

3.5 Logistics

[SYS4198] The System shall provide logistics support for OSP operations.

[SYS4200] The System shall process health and status data from all phases of mission operation to support logistics activities.

3.6 Personnel and Training

[SYS4310] The System shall provide a capability to train and certify personnel.

3.7 Segment Characteristics

Reserved

3.8 Legal and Regulatory

3.8.1 Environmental Impact

[SYS5000] The System shall limit orbital debris generation in compliance with NSS 1740.14, Guidelines and Assessment Procedures for Limiting Orbital Debris and JSC 27862, Post Mission Disposal of Upper Stages.

4 Verification

The Level II Requirements will be verified and validated as defined in the System Verification Plan (SVP), OSP-PLAN-023. The SVP defines the methods and the general approach to be taken to verify the Level II requirements through verification of Level III requirements with traceability back to Level II. Direct verification of requirements will be at Level III and lower, and by exception only at Level II.

4.1 Definition of Methods

Test - Verification by test is the actual operation of equipment during ambient conditions or when subjected to specified environments to evaluate performance.

a) Ambient Test - Ambient testing is an individual test or series of electrical or mechanical performance tests conducted on flight or flight-configured hardware and/or software at conditions equal to or less than design specifications. Its purpose is to establish that the system performs satisfactorily in accordance wit design and performance specifications. Ambient testing generally is performed at ambient conditions. Ambient testing is performed before and after each environmental test or major move in order to verify system performance prior to the next test/operation.

b.) Environmental Test - Environmental testing is an individual test or series of tests conducted on flight or flight configured hardware and/or software to assure the hardware will perform satisfactorily in its flight environment. Environmental test include vibration, acoustic and thermal vacuum. Environmental testing may or may not be combined with functional testing depending on the objectives of the test.

Analysis - Verification by analysis is a process used in lieu of or in addition to testing to verify compliance to specification requirements. The selected techniques may include systems engineering analysis, statistics and qualitative analysis, computer and hardware simulations, and computer modeling. Analysis may be used when it can be determined that:

A. Rigorous and accurate analysis is possible.
B. Testing is not feasible or cost-effective.
C. Similarity is not applicable.
D. Verification by inspection is not adequate.

Demonstration - verification by demonstration is the use of actual demonstration techniques in conjunction with requirements such as serviceability, accessibility, transportability and human engineering features.

Similarity - Verification by similarity is the process of assessing by review of prior acceptance data or hardware configuration and applications that the article is similar or identical in design and manufacturing process to another article that has previously been qualified to equivalent or more stringent specifications.

Inspection - Verification by inspection is the physical evaluation of equipment and/or documentation to verify design features. Inspection is used to verify construction features, workmanship, dimension and physical condition, such as cleanliness, surface finish and locking hardware.

5 Appendix A Traceability Matrix to Level 1 Requirements

The Level 1 parent requirement to SRD child requirement relationships are listed in Table I. The SRD child to Level 1 parent requirement relationships listed in Table II.

TABLE I. Level 1 Parents Traced to SRD Children

Level 1 Parent ID	SRD Child IDs
1.	SYS0710; SYS0190; SYS0200; SYS290; SYS0400; SYS0525; SYS0603; SYS0605; SYS0606; SYS1631; SYS0685; SYS0687; SYS0812; SYS0814; SYS1120; SYS1140; SYS1170 SYS1220; SYS1400; SYS1430; SYS1500; SYS1510; SYS1600; SYS1610; SYS1800; SYS1810; SYS2900; SYS2910; SYS3200; SYS3230; SYS3240; SYS3990
2.	SYS0200; SYS0205; SYS0230; SYS1120; SYS4020
3.	SYS0240; SYS0250; SYS0260; SYS0270; SYS0280; SYS0290; SYS0670; SYS0672; SYS0680
4.	SYS0687; SYS0930; SYS0980; SYS1620; SYS1630; SYS1640; SYS1650; SYS2570; SYS1910; SYS2302; SYS2310; SYS2500; SYS2820; SYS3500; SYS3000; SYS3050; SYS3100; SYS3250; SYS3274; SYS4198; SYS5000
5.	SYS0710; SYS0190; SYS0290; SYS0300; SYS0520; SYS0525; SYS0603; SYS0605; SYS0606; SYS0608; SYS1631; SYS0812; SYS0814; SYS1120; SYS1140; SYS1170; SYS1220; SYS1400; SYS1430; SYS1500; SYS1510; SYS1600; SYS1610; SYS1800; SYS1810; SYS3200; SYS3230; SYS3240; SYS3990; SYS4010;
6.	SYS0930; SYS0980; SYS1120; SYS1620; SYS1630; SYS1640; SYS1650; SYS2570; SYS1920; SYS2500; SYS2800; SYS2810; SYS2540; SYS2590; SYS2820; SYS3500; SYS2730; SYS3000; SYS3100; SYS3250; SYS3274
7.	SYS0150; SYS2100; SYS2950; SYS3210; SYS3260; SYS3400; SYS3410; SYS3420; SYS4198; SYS4310
8.	SYS3200
9.	SYS0150; SYS2001; SYS2020; SYS0130; SYS0131; SYS0132; SYS2100; SYS2120; SYS2950; SYS3400; SYS4200;
10.	SYS0195; SYS0608

TABLE I. Level 1 Parents Traced to SRD Children (Cont.)

Level 1 Parent ID	SRD Child IDs
OC1	SYS0100; SYS0120
OC2	SYS2400
OC3	None. The Level 1 is a "may." Outcome is architecture dependent.
OC4	SYS0550; SYS0700
OC5	SYS0410

TABLE II. SRD Children Traced to Level 1 Parents

SRD Child IDs	Level 1 Parent IDs
[SYS0100]	OC1
[SYS0120]	OC1
[SYS0710]	1, 5
[SYS0150]	7, 9
[SYS0190]	1, 5
[SYS0195]	10
[SYS0200]	1, 2
[SYS0205]	2
[SYS0230]	2
[SYS0240]	3
[SYS0250]	3
[SYS0260]	3
[SYS0270]	3
[SYS0280]	3
[SYS0290]	1, 3, 5
[SYS0670]	3

TABLE II. SRD Children Traced to Level I Parents (Cont.)

[SYS0672]	3
[SYS0300]	5
[SYS0400]	1
[SYS0410]	OC5
[SYS0520]	5
[SYS0525]	1, 5
[SYS0550]	OC4
[SYS0700]	OC4
[SYS0603]	1, 5
[SYS0605]	1, 5
[SYS0606]	1, 5
[SYS0608]	5,10
[SYS1631]	1, 5
[SYS0680]	3
[SYS0685]	1
[SYS0687]	1, 4a
[SYS0812]	1, 5
[SYS0814]	1, 5
[SYS0930]	4a, 4b, 6
[SYS0980]	4a, 4b, 6
[SYS1620]	4a, 4b, 6
[SYS1630]	4a, 4b, 6
[SYS1640]	4a, 4b, 6
[SYS1650]	4a, 4b, 6
[SYS1120]	1, 2, 5, 6
[SYS1140]	1, 5
[SYS1170]	1, 5
[SYS1220]	1, 5
[SYS1400]	1, 5

TABLE II. SRD Children Traced to Level I Parents (Cont.)

[SYS1430]	1, 5
[SYS1500]	1, 5
[SYS1510]	1, 5
[SYS2570]	4b, 6
[SYS1600]	1, 5
[SYS1610]	1, 5
[SYS1800]	1, 5
[SYS1810]	1, 5
[SYS1910]	4b
[SYS1920]	6
[SYS2800]	6
[SYS2810]	6
[SYS2001]	9
[SYS2020]	9
[SYS2100]	7, 9
[SYS2120]	9
[SYS2302]	4a
[SYS2310]	4a
[SYS0130]	9
[SYS0131]	9
[SYS0132]	9
[SYS2400]	OC2
[SYS2500]	4b, 6 (NPG8715.3)
[SYS2540]	6
[SYS2590]	6
[SYS2820]	4a, 4b, 6
[SYS3500]	4b, 6 (NPG8715.3)
[SYS2730]	6
[SYS2900]	1

TABLE II. SRD Children Traced to Level I Parents (Cont.)

[SYS2910]	1
[SYS2950]	7, 9
[SYS3000]	4a, 4b, 6
[SYS3050]	4a
[SYS3100]	4a, 4b, 6
[SYS3200]	1, 5, 8
[SYS3210]	7
[SYS3230]	1, 5
[SYS3240]	1, 5
[SYS3250]	4b, 6
[SYS3260]	7
[SYS3274]	4b, 6
[SYS3400]	7, 9
[SYS3410]	7
[SYS3420]	7
[SYS3990]	1, 5
[SYS4010]	5
[SYS4020]	2
[SYS4198]	4a, 7
[SYS4200]	9
[SYS4310]	7
[SYS5000]	4

6 Notes

6.1 Definitions

Annunciate: to provide a visual, tactile or audible indication.

Catastrophic Hazard: Any condition that may cause a disabling or fatal personnel injury, or cause loss of one of the following: the OSP, ISS, or major ground facility. For safety failure tolerance considerations, loss of the ISS is limited to those conditions resulting from failures or damage to elements of the ISS that render the ISS unusable for further operations, even with contingency repair or replacement of hardware, or which render the ISS in a condition which prevents further rendezvous and docking operations with ISS launch elements.

Certified for Use: The end result of the process by which the entity developing the GSE (whether contractor, government, or other agent) assures the GSE is ready for use and complies with the requirements levied by the Program and locale in which the GSE will be utilized. Examples: If the contractor develops the GSE, then the contractor provides the certification. If GSE is GFE (new, existing or modified) then the government provides certification for use. If the contractor modifies the GFE GSE then the contractor provides the certification for use.

Contingency Cargo: An item (or items) required to maintain the operability of the ISS and/or the health of its crew, and that must be launched as soon as possible.

Corrective Maintenance: Maintenance performed to restore system hardware integrity following anomalies or equipment problems encountered during system operations or as a result of conditions discovered during preventive maintenance.

Crew: Any human onboard the spacecraft after the hatch is closed for flight or onboard the spacecraft during flight.

Crew awake period: The time between the scheduled sleep periods.

Critical Software/Firmware: Software/Firmware that resides in a safety-critical system that is a potential hazard cause or contributor, supports a hazard control or mitigation, controls safety-critical functions, or detects and reports 1) fault trends that indicate a potential hazard and/or 2) failures which lead to a hazardous condition.

Critical Hazard: A condition that may cause a severe injury or occupational illness, loss of mission, or major property damage to facilities, systems, or flight hardware.

De-conditioned: "De-conditioned" defines a space flight crewmember or passenger whose physiological capabilities, including musculoskeletal, cardiopulmonary, and neurovestibular, have deteriorated as a result of long duration exposure to the micro-gravity and space environment and may result in degraded crewmember performance for nominal and off-nominal mission tasks. The space environment may include adverse effects of confinement, isolation, noise, deprivation of sensory and motor stimulation, and high workloads.

Definitive Medical Care: "Definitive Medical Care" is defined as a capability equivalent to a tertiary care/Level I hospital (trauma and neurosurgery capabilities) with a hyberbaric chamber facility.

Designed For Minimum Risk: Areas where hazards are not controlled using failure tolerance, but instead are controlled by specified margins of safety, factors of safety, material properties, or any other properties inherent to the design of the part, component, subassembly, or assembly, are called "Design For Minimum Risk". Examples of "Design For Minimum Risk" areas are structures, pressure vessels, pressurized lines and fittings, pyrotechnic devices, mechanisms in critical applications, material compatibility, and flammability. These areas are certified safe based upon their inherent properties to withstand their required usage as verified by analysis, qualification, and acceptance testing.

Emergency: Either an ISS emergency or Medical emergency unless specifically stated.

Firmware: The combination of a hardware device and computer instructions and/or computer data that reside as read-only software on the hardware device. Firmware can be Commercial Off-The-Shelf (COTS), Contractor developed, Government Furnished, or combinations thereof.

Flight Operations: All operations of the Flight Vehicle and the crew and ground teams supporting the flight vehicle from liftoff until landing.

Ground Operations: Those activities for pre-launch processing, launch operations and post landing operations associated with movement, processing, handling, support, integration, and test of the cargo and spacecraft elements.

Ground Processing: The work required to prepare the spacecraft for its mission from post-landing to launch. This work includes spacecraft*/crew recovery, spacecraft return to the processing facility*, spacecraft preparation at the processing facility, transport to the launch site, support during integration and checkout with the ELV, and launch countdown activities. The level of effort for ground processing is based on a standard workweek of two 8-hour shifts, 5 days a week.

[*Applies only to reusable spacecraft.]

Ground Support Equipment: Contract deliverable equipment (hardware/software) used on the ground to test, transport, access, handle, maintain, measure, calibrate, verify, service and protect flight hardware/software.

Habitable: The environment that is necessary to sustain the life of the crew and to allow the crew to perform their functions in an efficient manner. These environments are described in NASA-STD-3000.

Health & Status Data: Data, including Emergency, Caution and Warning data, that can be analyzed or monitored describing the ability of the system or system components to meet their performance requirements.

Ideal Velocity: Total velocity required without dispersions.

Ill or Injured: "Ill or Injured" is interpreted as a crewmember whose physiological and/or psychological well-being and health has deteriorated as a result of an illness (e.g. appendicitis) or injury (e.g. trauma, toxic exposure) and requires medical capabilities exceeding those available on ISS and transportation to ground-based definitive medical care. Ill or injured crewmember performance for nominal and off-nominal mission tasks will be degraded. Patients who are ill or injured are assumed to be stabilized to the extent possible prior to transport, bearing in mind the urgency for definitive medical care, the capabilities of the ISS, and the capabilities of the OSP.

Initial Capability: The initial capability of the OSP will begin when the crew rescue capability for OSP is available on ISS.

In Situ Maintenance: Maintenance performed at the operating location of the failed item or function.

Isolated from ISS Resources: The mated OSP is in a state of independence from ISS, and is fully operable using only its own resources.

Isolation: The mated OSP spacecraft is environmentally separated from the ISS and hatches on both ISS (OSP mating adapter) and OSP Spacecraft are closed.

ISS Emergencies: defined as fire, decompression (hull breach), loss of breathable air (ECLSS failure; toxins in air), or loss of station control.

Launch Opportunity: The period of time during which the relative position of the launch site and the ISS orbital plane permit the ELV to insert the OSP spacecraft into a target plane for a rendezvous with ISS within 72 hours (northerly launches only to avoid overflight of cuba). This re-occurs approximately every 23 hours and 36 minutes. A launch opportunity may consist of multiple launch windows of a few minutes each to account for different phasing requirements based on the time of rendezvous (Flight Day 1, 2, or 3).

Launch Probability: The probability that the System will successfully complete a scheduled launch event. The launch opportunity will be considered scheduled at 24 hours prior to the opening of the launch window.

Logistics Support: The planning, management, and technical activities concerned with supply, maintenance, transportation, and storage of goods and services to support Program objectives and sustain operation of the System.

Maintenance: The function of keeping items or equipment in, or restoring them to, a specified operational condition. It includes servicing, test, inspection, adjustment/alignment, removal, replacement, access, assembly/disassembly, lubrication, operate, decontaminate, installation, fault location, calibration, condition determination, repair, modification, overhaul, rebuilding, and reclamation.

Mission Planning: Pre-launch planning activity to support nominal and contingency flight operations, which includes advanced launch planning, manifesting cargo, trajectory analysis, timeline generation for required crew sleep shifting to sync to ISS sleep cycles, timelining of crew tasks in support of OSP launch through ISS docking, transfer of any cargo operations, and/or crew activities in support of OSP undock, deorbit and landing operations. Mission planning also encompasses OSP required activities for insuring operability while docked to ISS (health checks, maintenance, etc.) and the generation of procedures, displays, reference materials and flight rules necessary to conduct the entire set of mission phases.

Mission Preparation: The planning, analysis, and flight specific training required to prepare the System elements to execute a flight.

Nominal Mission Flow: The activities required for the System, post initial flight, to plan a mission, configure ground systems for a mission and process the spacecraft through launch countdown. A nominal mission flow is in support of a recurring mission.

Nominal Mission or Nominal Operations: Mission operations within the parameters of the three DRMs (transfer mission, medical rescue mission, and ISS evacuation rescue mission).

Ongoing Medical Treatment: As a minimum, continue the level of care provided on ISS and stabilization of the patient. In addition, respond to any new medical emergencies or contingencies.

Orbital Space Plane: The Program that encompasses all aspects of the System as well as the programmatic aspects involved in the design, development and operation of the System.

Plume Impingement: Physical contact of the OSP's thruster plumes with any structure.

Prepare the Flight Crew: The process and physical steps in which the flight crew is readied for launch utilizing appropriate infrastructure and ground support equipment to accommodate crew equipment donning, crew life support (e.g., cooling), transportation to and from the launch pad, safe ingress and egress into and from the OSP spacecraft, and crew equipment interface testing.

Preventive Maintenance: The function of keeping items in a specified operational condition.

Ready to be Transported (for an injured crewmember): means stabilized per accepted medical protocol (defined in JSC 26882).

Safety Critical: Functions, features, systems, status, or inhibits necessary to identify, prevent or control a critical or catastrophic hazard.

Spacecraft: The System flight element that serves as the crew rescue or crew transfer vehicle for ISS.

Software: Computer instructions or data, stored electronically. Systems software includes the operating system and all the utilities that enable the computer to function. Applications software includes programs that do real work for users, such as word processors, spreadsheets, data management systems, and analysis tools. Software can be Commercial Off-The-Shelf (COTS), Contractor developed, Government Furnished, or combinations thereof.

Status Alerts: Warning indications as a result of off-nominal or impending off nominal conditions.

Stowage: The accommodation of items in a safe and secure manner in the OSP spacecraft. This does not imply that resources other than physical accommodations (e.g. power, thermal, etc.) are supplied.

System: The aggregate of the ground segment, flight segment, and workforce required for crew rescue and crew transport

System Crew Rescue Availability: The probability, at any point in time, that the System is operational for crew escape (note: this is not quite the HQ definition given earlier)

Time Critical Items: Items that must be removed from OSP within a specified time.

6.2 Acronyms

COTS	Commercial Off-The-Shelf
CMO	Chief Medical Officer
DDMS	Department of Defense Manned Space Flight Support
DRM	Design Reference Missions
ECLSS	Environmental Control and Life Support Systems
ELV	Expendable Launch Vehicle
EVA	Extravehicular Activity
FAA	Federal Aviation Administration
GFE	Government Furnished Equipment
GSE	Ground Support Equipment
HRP	Human Rating Plan
HRR	Human Rating Requirements
HQ	NASA Headquarters
ICD	Interface Control Document
IDD	Interface Definition Document

IRD	Interface Requirements Document
ISS	International Space Station
ITAR	International Traffic in Arms Regulations
JSC	Johnson Space Center
LES	Launch and Entry Suited
LOC	Loss Of Crew
LSP	Launch Services Program
MCC-H	Mission Control Center – Houston
MOU	Memorandum of Understanding
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NEDD	Natural Environments Definition for Design
NGO	Northrop, Grumman, Orbital
NORAD	North American Aerospace Defense Command
NPD	NASA Policy Directive
NPG	NASA Procedures and Guidelines
NSS	National Safety Standard
OCD	Operations Concept Document
Ops	Operations
ORU	Orbital Replacement Unit
OSP	Orbital Space Plane
RMS	Reliability, Maintainability and Supportability
RQMT	Requirement
RSS	Root Sum Square
SRD	System Requirements Document
SSP	Space Station Program
SVP	System Verification Plan
TBR	To Be Resolved
TBS	To Be Specified
TDRSS	Tracking and Data Relay Satellite System
UP	The MSFC Organizational Code for the OSP program