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THE SPACE SHUTTLE AND FUTURE SPACE LAUNCH VEHICLES

HEARING

BEFORE THE

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

ONE HUNDRED EIGHTH CONGRESS

SECOND SESSION

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ONE HUNDRED EIGHTH CONGRESS

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THE SPACE SHUTTLE AND FUTURE SPACE LAUNCH VEHICLES

WEDNESDAY, MAY 5, 2004

U.S. SENATE,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The Subcommittee met, pursuant to notice, at 2:37 p.m. in room SR–253, Russell Senate Office Building, Hon. Sam Brownback, Chairman of the Subcommittee, presiding.

OPENING STATEMENT OF HON. SAM BROWNBACK, U.S. SENATOR FROM KANSAS

Senator BROWNBACK. Good afternoon. Thank you all for joining me. The reason for my delay is, because I thought we had a vote at 2:30. They did have it scheduled for 2:30, but it has been moved to 2:45. So I thought what we'd do is try to get the hearing underway, and see how far we can proceed, because these things have a way of sliding on us. We're not the only ones that have trouble keeping schedules. But we'll want to move on through the hearing.

Today, we're going to consider something that is difficult, rocket science. Some years ago, a major cruise ship company coined a phrase that "getting there is half the fun." Nowhere is that truer than for space travel. Rocket scientists tell us that once a spacecraft is in low-Earth orbit, just a few hundred miles above us, we're halfway to anywhere in the solar system, including the Moon and Mars.

This first step, lifting off the Earth and entering low-Earth orbit, is expensive and dangerous, but it's part of space travel. Astronauts or robotic spacecrafts spend the first few minutes of their journey into space sitting atop a rocket that releases as much energy as that contained in a small atomic bomb. The cost and risk of getting into space has not changed in the almost-half-century since we began space travel.

Today, our primary means of getting people and equipment into space for NASA is the Space Shuttle. It's a magnificent piece of technology. However, twice in the past 20 years, it has failed, taking the lives of 14 astronauts with it. It's expensive, as well, costing the American taxpayer effectively a billion dollars per flight. Today, it's grounded, and we are relying on foreign hardware to get our people into space and maintain the International Space Station.

A few months ago, the President announced a new vision, focused robotic and human exploration of the solar system, beginning with the Moon and Mars. I support the President's vision and like many of my colleagues in the Congress, need some more information from NASA and the space community on key issues. None is more critical than access to space, and that's why we're here today.

I see three related questions:

First, we need to understand the true status of the Space Shuttle and its return to flight. Implicit in this issue is whether we might be better off phasing out the Space Shuttle sooner than the President's 2010 date, and use the resources to move the schedule for our expansion into the solar system forward.

The second question is how best to meet our international commitments with respect to the International Space Station with less or perhaps no use of the Space Shuttle at all. This is a key question, one which we cannot address in full detail today, but I hope to get started on. Thus, I intend to hold further hearings on this, including a field hearing, I hope, in California later this month.

Finally, the experts tell us that to accomplish the President's bold goals in exploration beyond low-Earth orbit requires much larger payloads than we can launch today. The Shuttle and our military big rockets, the EELV, can put about 20 tons into low-Earth orbit. We may need five times that per launch, which is feasible due to such giant rockets as Saturn V, from the Apollo program. Soviet Union built a huge booster to launch similar payloads during the Moon race, and again in the 1980s to launch enormous space weapons; these programs are all gone. So we must ask our space community how they might reconstitute the capability, and how much it will cost.

Let me now turn to the Space Shuttle. Since I assumed the chairmanship of this Subcommittee over a year ago, I've asked repeatedly whether we might be off phasing the Space Shuttle out soon and I know that my questions are disturbing to many. Some of my colleagues in the Senate have rallied to the defense of Space Shuttle, and I expect to hear more on that today, which is how it should be. We should have a vigorous discussion and debate about the Shuttle program, where those who see something to lose will be vigorous opponents of the new direction. Conversely, those with something to gain in the future are only lukewarm supporters at times. Despite this opposition, I intend to continue to press these questions and to ask the serious questions about the future of the Space Shuttle program.

I've asked NASA to tell us today what they are doing and how well it's going on returning the Shuttle to flight. I also asked NASA what they're doing to find alternatives to the Space Shuttle for completing the International Space Station. The Commercial Space Act of 1998 calls for maximum use of commercially provided services in support of the International Space Station. I've been approached by a number of commercial providers of such services, some of which believe they can provide most, if not all, support services needed to complete and maintain the Space Station and meet our international commitments.

In 2002, the United States Alliance, who operates the Space Shuttle for NASA, recommended that roughly a third of the Shuttle flights be offloaded to other vehicles. For our hearing at the end of May, I'll ask that NASA describe their approach to making fuller use of this private-sector capability. We want to, and we need to, examine these ideas as we move forward in the future.

A week ago, we held a hearing to consider what other nations are doing in space exploration and heard that many nations have aspirations of human exploration and expansion to the Moon and Mars. Experts agreed that nations such as China will expand into space regardless of what we do. I, for one, believe we must not ever be in a position of explaining to our children why others are walking on the Moon and Mars, as well as reaping the benefits of space, while we are not. Fortunately, we have an advantage that others do not in that we have a private sector that can do anything, if only given a legitimate chance. We also have a great deal of ingenuity, in ourselves, that we can move forward on these programs.

The American people can have a space program that leads the world—which is the current situation—and we need that in the future. It can be a space program firmly embedded in opportunity for all, and that's what I want to examine today.

I believe President Bush has set us on the right path to an unlimited space future. I strongly support this exploration vision and program, and urge my colleagues in Congress to do the same.

To give you a bit of an idea of where I hope we can go, I want to hold this hearing today. We'll have a field hearing, I hope, in Southern California to look at other prospects for being able to take care of Space Shuttle, the Moon/Mars missions, and different ideas that people there might have. And then, from that point forward, I hope we're going to be able to put forward legislative language, authorizing language, in looking at how we might move forward.

I see that the commission the President appointed had its last field hearing yesterday, in New York, on Moon and Mars. I'm looking forward to their report and what they have coming out, which then I hope we can put together in: "What's the architecture for our space program and manned space mission into the future?"

Delighted to have our panels here today with us to testify, and we'll start off with the first panel, Mr. William Readdy, Associate Administrator for Spaceflight of NASA, and Rear Admiral Craig Steidle, Associate Administrator for Exploration Systems out of NASA, as well.

Gentlemen, thank you for joining us. We're going to continue this as long as we can, and then I may have to put us in recess for a brief period of time. We look forward to your presentations.

Mr. Readdy?

STATEMENT OF WILLIAM F. READDY, ASSOCIATE ADMINISTRATOR FOR SPACEFLIGHT, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION; ACCOMPANIED BY REAR ADMIRAL CRAIG E. STEIDLE, U.S. NAVY (RET.), ASSOCIATE ADMINISTRATOR FOR EXPLORATION SYSTEMS, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. READDY. Yes, sir. Thank you, Mr. Chairman. And I appreciate you holding the field hearing, particularly, there at Clear Lake, to address the exploration vision. I also thank you for the opportunity to testify before you today. And Craig Steidle, Associate

Administrator for Exploration Systems, is with me, and he'll be available to take your questions.

Earlier today, I had the opportunity to meet with NASA's newest astronaut candidate group. The class will be announced tomorrow at the Udvar-Hazy facility out at Dulles. This is a very impressive group of individuals, and I hope you'll have a chance to meet them soon. They're the ones that will lead us in the next steps to NASA's new exploration vision.

Let me begin with the vision for space exploration. It is to advance U.S. scientific, security, and economic interests through a robust space exploration program. The vision is bold and forward-thinking, yet practical and responsible. Fundamentally, it is not about a particular launch vehicle or other hardware, but the relevance and value that space exploration brings to our lives daily.

The Space Shuttle and International Space Station programs provide transition paths into this next era of space exploration. They're a bridge between what we've learned from this extraordinary first-generation reusable-launch system and the long-duration spaceflight experience that we have on International Space Station and our future.

The focus of the Space Shuttle is to complete assembly of International Space Station, including U.S. components that support our exploration goals and those provided by our foreign partners so that we can conduct the research necessary to prepare us for our journey beyond low-Earth orbit. And, as you said, Robert Heinlein's quote is: "Earth orbit is halfway to anywhere in the solar system." And, indeed, it's true, in terms of energy.

No other vehicle in the world can do the Shuttle's job today, which is in a class by itself, in terms of performance and volume. It's a unique mix of cargo, crew, robotic capability, rendezvous and docking capability, and the ability to return payloads to Earth.

There's a lot of launch capacity out there today. New vehicles are currently under development and are being conceived in the private sector. But the other launch vehicles that are available, even the ones at the heavy-lift end of the spectrum, Titan IV and Delta IV Heavy, had no existing rendezvous, docking, or robotics capability; they do not carry crew; they cannot currently support ISS assembly; and they cannot return payloads to Earth.

The ISS was designed to be carried into space and assembled using the Space Shuttle. The elements have already been built, tested; and most of them are integrated and awaiting launch at the Kennedy Space Center. Switching to expendable launch vehicle at this point would result in what we estimate to be a minimum of four to 5 year's delay in resuming ISS assembly, and require significant investments to add new capabilities, as well as redesign and retesting of those Space Station elements. Therefore, NASA believes the most responsible way forward is to use the unique capabilities of the Shuttle for assembly, return of payloads to Earth, and crew transport.

The best role, however, for commercial launch services, is to provide future ISS resupply. And NASA seeks to release a request for proposal in mid-2005 to acquire capability for meeting resupply requirements after ISS assembly is completed.

As we look to the future, all options to meet launch requirements are on the table and NASA's wide-ranging missions require a variety of launch services. To meet these customer needs, NASA already uses a mixed-fleet strategy to purchase commercial launch services from a range of providers, as well as launches provided by our international partners; NASA has historically supported emerging launch companies. Through a biannual on-ramp of the NASA launch-services contract that occurs every February and August, we invite companies with new launch capability to submit their proposals for NASA consideration. Also, NASA will hold a pre-proposal conference next week at the Kennedy Space Center regarding small-launch capability.

NASA also partners with the Department of Defense, Defense Advanced Research Projects Agency, and the Air Force, all of whom have interest and requirements requiring small launch vehicles.

With regard to heavy-lift capability in order to support the vision for space exploration, my office is working very closely with Craig Steidle and his staff to understand the requirements for space exploration and conduct the trade studies necessary to meet those requirements. Those trade studies include evolving the existing fleet of expendable launch vehicles, the potential for using Space Shuttle components, and the potential for clean-sheet new vehicle designs. We're also reviewing previous lessons learned as a way to springboard future studies to support the unique requirements of the crew exploration vehicle. These activities will position us for future acquisition of heavy-lift capability.

With this vision, we are embarking on a journey, not a race. We begin this journey of exploration and discovery knowing that many years of hard work and sustained effort will be required, yet we look forward to achieving these concrete results in the near term.

The vision requires decisions to secure long-term U.S. space leadership. This vision provides an exciting set of major milestones with human and robotic missions, like there is currently ongoing in Mars, and onboard the International Space Station with Expedition 9, and invites new ideas and innovation in the private sector. Accomplishing this bold, new vision will provide the opportunity for new generations of Americans to explore, innovate, discover, and enrich our Nation in ways unimaginable today.

Thank you, sir.

[The prepared statement of Mr. Readdy follows:]

PREPARED STATEMENT OF WILLIAM F. READDY, ASSOCIATE ADMINISTRATOR FOR SPACE FLIGHT, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. Chairman and Members of the Subcommittee, thank you for this opportunity to appear today to discuss the Space Shuttle and future launch vehicles. When the President visited NASA Headquarters on January 14 and announced the Vision for Space Exploration, he presented a vision that is bold and forward thinking, yet affordable and achievable. He stated that the first order of business was to safely return the Space Shuttle to flight as soon as practicable, complete assembly of the International Space Station (ISS), and fulfill the commitments to our International Partners. Once the ISS assembly is complete, planned for the end of the decade, the Space Shuttle—after nearly 30 years of duty—will be retired from service. These are the first steps on the journey to fulfill the Vision for Space Exploration.

After the *Challenger* accident, NASA has relied on a Mixed Fleet Launch Strategy to meet the launch requirements of NASA's diverse program objectives. This Mixed Fleet Launch Strategy takes advantage of both domestic and partner launch capability and enables focused use of the unique Space Shuttle capabilities. Our approach enables us to continue to support the ISS through reliance on partner assets, while NASA addresses the Columbia Accident Investigation Board (CAIB) recommendations and focuses on returning the Shuttle safely back to flight. Since the *Columbia* accident, NASA has continued flying important science missions, including deployment of the Space Infrared Telescope Facility, now called the Spitzer Telescope, and the back-to-back Mars missions last summer on domestic commercial launch systems. NASA expects to continue this Mixed Fleet Strategy as we embrace the new challenges of the Vision for Space Exploration.

Space Shuttle Return to Flight

As the loss of *Columbia* and her crew has reminded us, working in space is inherently risky. The CAIB recognized the risks associated with operating the Space Shuttle and made its recommendations consistent with the overriding objective of safety. NASA recognizes these risks and is working to mitigate them, while moving forward to accomplish our missions.

On April 26, 2004, NASA provided to Congress the latest version of *NASA's Implementation Plan for Space Shuttle Return to Flight and Beyond.* This plan details the currently anticipated work schedule and cost estimates for Return to Flight (RTF) activities so that we can safely return the Space Shuttle to flight. In addition to providing updates on NASA's progress towards RTF, the implementation plan recognizes the long-term goals of human planetary exploration outlined in the Vision for Space Exploration.

The planning window for the next launch of the Space Shuttle is currently scheduled for March 6, 2005—April 18, 2005. Prior to launch, NASA must successfully address all fifteen RTF recommendations from the CAIB. The RTF Task Group, chaired by Richard Covey and Thomas Stafford, is charged with assessing the implementation of these recommendations. The Task Group, as of April 15, 2004, agreed to close three RTF recommendations. The three recommendations that have been closed are:

- *Recommendation 3.3–1*—Develop and implement a comprehensive inspection plan to determine the structural integrity of all Reinforced Carbon-Carbon system components. This inspection plan should take advantage of advanced non-destructive inspection technology.
- *Recommendation 4.2–3*—Require that at least two employees attend all final closeouts and intertank area hand-spraying procedures.
- *Recommendation 6.3–2*—Modify the Memorandum of Agreement with the National Imagery and Mapping Agency to make the imaging of each Shuttle flight a standard requirement.

NASA is committed to addressing all CAIB recommendations, as well as self-initiated "raising the bar" actions. The updated implementation plan shows that NASA continues to make progress in all efforts to make the Shuttle safer. The revised schedule for implementing the CAIB recommendations shows that NASA has a deliberate approach for achieving all necessary milestones required to close each action item.

When we return to flight, the Space Shuttle will be the safest it has ever been. NASA has confidence in its ability to maintain that level of safety throughout the life of the Space Shuttle program. NASA is also confident that the Space Shuttle program can accomplish its role in the Vision for Space Exploration to complete International Space Station assembly.

The focus of the Space Shuttle will be finishing assembly of the International Space Station (ISS). With its job done, the Space Shuttle will be phased out when assembly of the ISS is complete, planned for the end of the decade. NASA will determine, over the next year, how best to optimize the use of the Space Shuttle fleet for the remainder of its service life, and what investments are required to ensure its safety, reliability and maintainability during this period.

International Space Station

NASA plans to complete assembly of the International Space Station (ISS) by the end of the decade, including those U.S. components that will ensure our capability to conduct research in support of the new Vision for Space Exploration goals and those components planned and provided by our International Partners. The unique capabilities of the Space Shuttle are essential to the successful completion of the ISS. The ISS and its elements, most of which are already built, have been designed to take advantage of the more benign Shuttle flight environment in the Shuttle's cargo bay, removed and repositioned by the Shuttle's robotic arm, and connected together by the Shuttle's astronaut crews during space walk activities.

The International Space Station (ISS) research plans, assembly sequence, and final configuration are being re-examined as part of the Agency refocus to meet the Vision for Space Exploration. How we support the ISS through its assembly and operational phases is also under re-examination. NASA will continue its Mixed Fleet Launch Strategy and optimize existing partner assets as we assess opportunities using domestic capabilities to support the ISS. NASA is targeting completion of the re-evaluation of assembly, utilization, logistics, and maintenance requirements of the ISS for later this summer. The ISS program is currently working closely with our International Partners to develop a plan for meeting the revised requirements. We expect a refinement of our Mixed Fleet Launch Strategy including Space Shuttle launch requirements needed to complete assembly of the ISS to be an outcome of this process.

The ISS Mixed Fleet Strategy concept of operations for the ISS has, to date, included the Space Shuttle and Russian provided Soyuz and Progress vehicles. In the future, it will also include the European Automated Transfer Vehicle, and the Japanese H–II Transfer Vehicle, which are both currently under development. NASA is also evaluating opportunities for augmenting the Mixed Fleet with additional domestic launch systems. To this end, the President's FY 2005 Budget Request includes funding for initiation of an ISS crew and cargo capability. NASA plans to release a request for proposals in mid-2005 to acquire capability for meeting ISS operations requirements as soon as practical and affordable.

The ISS offers us a tremendous opportunity to study human survival in the hostile environment of space and assess how to overcome the technology hurdles to human exploration beyond Earth orbit. NASA research activities aboard the ISS will be focused to support the new exploration goals, with an emphasis on understanding how the space environment affects astronaut health and capabilities, and on developing appropriate countermeasures to mitigate health concerns. ISS will also be vital to developing and demonstrating improved life support systems and medical care. Over the next year, the Biological and Physical Research Enterprise will conduct a thorough review of all research activities to ensure that they are fully aligned with and supportive of the new Vision for Space Exploration.

The ISS is preparing us for future human exploration in many ways. It is an exploration research and technology test bed. It is a platform that represents an unprecedented accomplishment for space engineering and on-orbit assembly of unique and complex spacecraft. It is a model for future space operations, linking mission control centers on three continents to sustain space flight on-orbit operations—twenty-four hours a day, seven days a week—by an international team composed of representatives from the U.S., Russia, Europe, Japan and Canada. Perhaps the most significant contribution of the ISS Program is that it is a foundation for international partnerships and alliances between governments, industry, and academia in space exploration. The success of the ISS assembly to date and its continued successful operation during the absence of the Space Shuttle launches is a tribute to the engineering excellence and successful cooperation of the international team.

The capability of this model is further evidenced by the successful launch of a new crew to the ISS and the return to Earth of the previous crew last week. The Expedition 9 crew, NASA ISS Science Officer Mike Fincke and Russian cosmonaut Commander Gennady Padalka, were launched to the ISS from Baikonur Cosmodrome in Kazakhstan on April 18, 2004 EDT on ISS Flight 8S (Soyuz TMA–4). Finke and Padalka, along with European Space Agency astronaut Andre Kuipers of The Netherlands, docked to the ISS on April 21, 2004 EDT.

After a week and a half of successful experimentation and handover activities, Kuipers then joined the Expedition 8 crew, Commander and NASA ISS Science Officer Mike Foale and Russian cosmonaut Flight Engineer Alexander Kaleri on ISS Flight 7S (Soyuz TMA–3) for their return to Earth April 29, 2004, 8:11 PM EDT.

Mission Control Center (MCC)-Houston and MCC-Moscow continue to work closely and efficiently to resolve anomalies, perform avoidance maneuvers, monitor Soyuz and Progress dockings, and re-boost and reorient the ISS as required. There are ongoing ISS technical challenges, but the corrective maintenance is performing better than anticipated. Anomalies are being addressed, and overall the system is consistently stable. The operations teams have successfully resolved system anomalies, but continue to watch crew heath maintenance systems, Russian life-support systems, attitude control, and various components of cabin pressure. All of these on-orbit scenarios and changing situations from which we are prepared to safely deal with and learn from, will better enable NASA to fulfill the Vision for Space Exploration.

International Space Station Assembly Transportation Alternatives

To meet the goals laid out in the Vision for Space Exploration, NASA is evaluating the current manifest for flights to the ISS. To complete ISS assembly b the end of the decade, NASA is reviewing the assembly sequence and final ISS configuration, as well as the complement of currently available and proposed domestic and international vehicles that are capable of delivering crew and cargo to and from the ISS, and the predicted Shuttle return to flight date. This evaluation, which will factor in the historic turn around time between Shuttle flights, is expected to be complete in the summer and will provide a better idea of how many Shuttle flights will be needed to complete assembly of the ISS. NASA will trade ISS requirements against launch capabilities to ensure that the Shuttle can be operated safely and the ISS assembly can be completed by the end of the decade, consistent with the Vision for Space Exploration.

Conducting ISS assembly mission using vehicles other than the Shuttle would be very difficult. Prior to and since the *Columbia* accident, NASA has assessed alternative launch capabilities to support ISS assembly in addition to crew and cargo resupply studies. The difficulty in replacing the Shuttle in ISS assembly is that ISS elements and partner facilities have been designed to take advantage of the Space Shuttle's unique volume and performance, and more benign launch environment. None of the domestic or partner launch systems have the capability to meet requirements for assembly of remaining ISS elements without significant modification of either the vehicle or the ISS elements.

For example, NASA could invest in upgrades to the heaviest planned versions of domestic Expendable Launch Vehicles (ELVs) to address current mass and volume shortfalls. There remain, however, significant challenges that drive risk, schedule, and cost to accommodate the transition in operations concept for ISS assembly items that are already built and designed specifically for the Shuttle capabilities and launch environment. The most driving challenge is how to define a new operations concept and assembly process that uses ISS crew without the benefit of the Shuttle's remote manipulator arm or space walking crewmembers to safely complete each assembly mission. Investment would also be required to develop a domestic transfer vehicle capability and define new operations concepts to enable ELV deployment and element rendezvous and docking with ISS. The existing ISS structures and facilities would need to be redesigned to meet the new ELV flight environment and would also need to develop an ELV carrier to replicate Shuttle attach points. Due to multiple parallel development and test schedules that would be required, NASA estimates that canceling the Shuttle now and using only ELV's to build the ISS would result in a minimum four to five year delay in restarting ISS assembly.

The significant challenges and risks associated with replicating the Shuttle's capability for the remaining assembly flights have led NASA to focus on use of the Shuttle for assembly of the ISS, while continuing to pursue alternatives to the Space Shuttle for non-assembly tasks and post-Shuttle ISS support.

Partnerships

The Office of Space Flight is working closely with the Office of Exploration Systems and the Department of Defense to understand evolving launch requirements to ensure an integrated National launch strategy within the stagnant launch market. NASA, the United States Air Force, and the National Reconnaissance Office held the fourth Government and Industry ELV Mission Assurance Forum on March 9–10, 2004. At this year's forum NASA shared lessons learned from the CAIB review of the Space Shuttle program as we are applying them to our launch services program.

This forum was originally established by our agencies to ensure that the lessons learned from the 1998 Presidential Broad Area Review into ELV launch failures are not forgotten. The Broad Area Review identified the importance of government users to serve as knowledgeable buyers of launch capability and the benefit of value added government technical oversight to enhance mission success. A critical lesson not to be relearned is the importance of added government diligence in the area of systems engineering when programs and their contractors are in periods of transition and/or under severe cost pressures. This is exactly the environment the Nation faced in 1998.

To formalize our cooperative efforts, NASA and members of the Defense community established the Partnership Council in 1997 to provide an opportunity for the senior space principals to meet face-to-face on a regular basis to discuss issues relevant to the space community. The purpose of the Partnership Council is to facilitate communication between the organizations and to identify areas for collaboration and cooperation. Much of the benefit of the Partnership Council is the day-to-day activities and relationships built within the government community engaged in space.

Summary

NASA's Mixed Fleet Launch Strategy is being updated to address the Vision for Space Exploration. NASA is developing a strategy to acquire ISS crew transport, as required, and cargo transportation as soon as practical and affordable. NASA envisions that commercial and/or foreign capabilities will be the building blocks for our future Mixed Fleet Launch Strategy, as it has served us well. NASA remains confident that the Space Shuttle can be operated safely for the remainder of its service life and the ISS can be completed by the end of the decade consistent with the Vision for Space Exploration and our international commitments.

Senator BROWNBACK. Thank you, Mr. Readdy.

Admiral Steidle, would you care to make a statement, or do you just want to respond to questions?

Admiral STEIDLE. I just want to respond to your questions, sir. Thank you.

Senator BROWNBACK. All right. Thank you very much.

Mr. Readdy, I believe you mentioned in your testimony that if we move away from the Shuttle, it would delay the finishing of ISS by 4 to 5 years. Is that correct?

Mr. READDY. Yes, sir, that's correct.

Senator BROWNBACK. NASA has studied the option about decommissioning the Shuttle and going another way to finish ISS, is that correct?

Mr. READDY. Yes, sir, we have. And the study that I referred to here, and the procurement that we're talking about in 2005, is contained our budget request for $140 million. And we intend to replicate the up-and-down mass of the Shuttle. Thus far, our discussions with the industry reps estimate that there is between 700 and a billion dollars of nonrecurring costs, and then recurring costs for a flight rate of eight to twelve per year to meet our requirements, which means the development time, as I said earlier, is somewhere between 3 and 5 years.

Senator BROWNBACK. Well, let me back up on that, then. So if we just said, "OK, we're going to take the Shuttle, and we're not going to fly the Shuttle anymore," how would you then finish ISS? What would be the systems that would be used to finish ISS, in the study that NASA has done?

Mr. READDY. Well, right now, it would require a complete redesign of the hardware that we already have tested, built, and integrated at the Kennedy Space Center. So one issue is that the existing hardware would have to be deintegrated. It would probably have to be redesigned and certainly re-analyzed, then repackaged to launch on expendable launch vehicles.

The other things that would be required are to develop the autonomous rendezvous, docking, and robotic capability, as well as new payload fairings and interfaces for whatever vehicle might be chosen in order to lift something that heavy to the International Space Station orbit.

Senator BROWNBACK. How would it be lifted up? You're saying you'd have to develop new capacity, or is there private-sector groups that have put forward proposals to you to lift this?

Mr. READDY. At this point, sir, there are two remaining Titan IVs, which are the only equivalent to the Shuttle cargo bay, in terms of capacity. Also, Titan IV doesn't have robotic, rendezvous or docking capability. There are only two of those launch vehicles left in the inventory, and they're committed to national security purposes; I think they launch in 2005.

The nearest-term heavy-lift vehicle currently available is Delta IV. The very first test flight of that is supposed to be in the fall of this year in order to try and replicate a similar 20-ton-to-orbit capacity. And, once again, it has no rendezvous, docking, proximity ops, or robotics capability to accommodate the unique hardware of the International Space Station.

Senator BROWNBACK. What about anything that the Russians or other countries have that could carry out the lift capacity of the final pieces of ISS?

Mr. READDY. That's a good question, sir. In 1993, in the Space Station redesign we conducted in Crystal City, we looked at a variety of alternatives, such as launching the International Space Station in three major elements, or looking at it as a Russian derivative. In the end, the option that we chose was a hybrid.

The Russians have launched hardware to the International Space Station, including the FTB, which is the propulsion module that's up there right now, a service module, and other very small pieces with their Soyuz boosters, which do have a Proton capability, but that does not suffice to boost the large elements that we have; nor does it have robotic capability.

Senator BROWNBACK. You mentioned, though, about taking the large elements we have, and reconfiguring them. Are you suggesting breaking those down into smaller parts to be able to lift?

Mr. READDY. Sir, I'm not even sure that that's feasible. At this point, we haven't even looked at how complex it would be to do that.

Senator BROWNBACK. But in NASA's analysis of the future use of the Space Shuttle, and then shipping them up on a Russian vehicle analyzed?

Mr. READDY. We don't think that that's feasible right this minute nonetheless, and our near-term objective, spelled out in the vision for space exploration is to return the Shuttle to safe flight in accordance with the Columbia Accident Investigation Board's findings and recommendations, which we're on track to do; we were reviewed last week by the Stafford-Covey Task Group. Also, we have the "Space Shuttle Return to Flight and Beyond" implementation plan that was just issued last week. And we're making steady progress toward returning to flight in March or April of next year.

Senator BROWNBACK. Now, if we don't return the Shuttle to flight, have you contacted the Russians about the possibility of them taking up more of the parts to finish the ISS? If yes, whether or not they would be able to do so? Could they reconfigure some of their work or could we reconfigure the parts, in order to lift the equipment into space?

Mr. READDY. Well, I have to commend all our partners for how well, during the Shuttle down period, we have operated together; the Europeans have been particularly supportive, as have the Russians. Certainly, they have launched all the crew members to International Space Station here in the interim—most recently, Expedition 9. They have also launched progress vehicles for propellent, food, water, and some limited spare parts.

Our current operation, though, is constrained by logistics. Just like an expedition to Antarctica or a deployed carrier battle group, logistics drives exploration. It did in Shackleton's time, during his voyages. At the moment, we have reduced the crew onboard to two crew members in order to be sustainable, given the Progress resupply vehicles that we have available to us today.

The Russians and we both learned, during the Shuttle-Mir era, that Progresses alone were not sufficient. In terms of the partnership, though, we have the ATV, which is the autonomous transfer vehicle, being designed and built by the European Space Agency right now, over in Bremen and is being integrated. The ATV should be ready for flight next year aboard an Ariane V launch vehicle that will provide additional logistics redundancy and a much larger capacity, similar to what the multipurpose logistics module can launch.

Senator BROWNBACK. Let me sharpen this question, because I'm going to have to put us in recess right after this.

Have you contacted the Russians about them being able to finish ISS, and said: "Would you look at this? Do you have the capacities? And over what time frame and cost would it take for you to finish this?"

Mr. READDY. We have a heads-of-agency meeting that's planned for the end of July over in Noordwijk, Holland, where the heads of all the agencies—Canadian, Russian, European, and Japanese—will meet with the NASA Administrator, where we're going to discuss the way ahead and what we view to be the trades involved in the final configuration of International Space Station.

At this point, the Russians were, in fact, relying on Shuttle for logistics up front, such as to launch their power platform. Therefore, we're going to have to engage in this dialogue with our partners to establish what the way ahead may look like.

Senator BROWNBACK. The reason I'm asking the question that a lot of Members are asking right now, is because Shuttle's done great work, but it is very expensive to operate. Do we need to continue this, or is there another way to finish ISS without the Shuttle? And I realize there's a very clear answer here of, say "No, we just need to get the Shuttle back and flying, because that's the way it's all configured, and that's the way it's designed to operate." And I understand that answer, which is a legitimate response. I just want to make sure that we have looked at all other possible options regarding this. If we're going to move on to another set of missions, is there another way, or have we examined all of the other options?

Mr. READDY. Yes, sir. What we are doing is, we are critically reviewing the manifests in the way ahead to make sure that each and every one of those flights buys its way in, that each and every one of those, not only in sequence is required, each and every one of those capacities is required to support exploration. Because that's what this is about—going to the vision—is to inform us on countermeasures to support humans for long duration in Earth orbit, so that we can go beyond low-Earth orbit. And that requires a larger capacity than we have onboard International Space Station right now, a larger number of crew members, potentially scores of crew members, as opposed to right now, where we can fly four crew members per year in the current configuration.

So clearly that's something that we are looking at within the International Space Station program, in terms of, not only assembly, but how to get way up on the glide slope in terms of logistics, so it will be sustainable for the long term using other modalities, as opposed to Shuttle.

The line-replaceable units for International Space Station, those major assemblies, like the control momentum gyros, were designed, from the very beginning, to be maintained on the ground, refurbished on the ground, troubleshot on the ground, and then launched again. So we're going to have to look completely at the logistics tale for International Space Station and see what other modalities we might use when we no longer have the Shuttle available for down-mass and up-mass for large assemblies.

Senator BROWNBACK. Mr. Readdy and Admiral, if you can stay around for a few minutes, I need to go over and vote. We're at the back end of this vote. I'll vote and then be back. We'll probably be in recess about 15 minutes.

Thank you.

[Recess.]

Senator Brownback: We'll call the hearing back to order. Sorry for the extended recess.

Mr. Readdy, I want to follow up on the line of questioning we were on before I left. Also, let me say at the outset, I appreciate the great work you folks do at NASA. So, I apologize for the pointed questioning at times, but we're looking at where we're going to invest in the next set of technologies, and the decisions made now will have impact for decades to come. Hence, I want to make sure that we're making the right sort of decisions and we have all the information in front of us when we make these decisions.

That's why I'm asking about particularly our inquiries to the Russians or the private sector on finishing ISS, which seems to be the major reason for continuing to have the Space Shuttle at this point in time; that is, to finish ISS. Would that be correct?

Mr. READDY. Yes, sir. And if I could clarify my previous answer with respect to Russian capability, European capability, private-sector capability—I think a trip down to the Space Station processing facility to actually see the hardware would be extremely instructive. Like a picture is worth a thousands words, when you go down there, you see the building and see it full of the hardware that has already been tested, checked out, integrated, and ready for launch, some people have an impression of Space Station, because it is modular, that it's an Erector Set or it's a Lego set that can be taken apart and put back together again. But when you get down there, and if you see each one of those launch packages, you realize just how complex a truss element is; it contains electronics that go into it. And because it goes around the Earth once every hour and a half, it experiences extremes in temperature from being in sunlight and in darkness. And the entire Space Station has to play together as an integrated element; Russian elements, Japanese elements, European elements, and our own. To repackage any of those, irrespective of what kind of launch vehicle, to change the loads from what the Shuttle experiences, which are relatively benign during ascent, only three Gs, where we throttle the main engines back for about the last minute or so before main-engine cutoff, as Senator Nelson's familiar, that provides a very benign set of loads. So the Space Station hardware has a very minimal set of design requirements for launch. If we were to repackage it, put it on any other kind of launch vehicle, it would require extensive analysis, possibly redesign, and de-integration/reintegration, sir.

Senator BROWNBACK. I think you or the Administrator have previously mentioned it previously to me that you would have to do that.

My question really is, have we searched through all the options thoroughly?

Mr. READDY. Yes, sir, we think we have.

Senator BROWNBACK. Well, let me ask specifically, though, because your—very troubling to me earlier, when I asked you if you had officially contacted the Russians about them finishing ISS; and I take it from your answer, we have not.

Mr. READDY. Sir, we are in constant communications with the Russians in this partnership. The Administrator met with Mr. Perminov just last week while we were over there for the Expedition 8 landing, and we discussed a number of issues, all having to do with the final configuration of International Space Station. A number of those are intended to be readdressed when we have the heads-of-agency meeting with the other partners, and that is planned for the end of July over at Noordwijk, Holland.

Senator BROWNBACK. But we have not officially asked the Russians, "Could you finish ISS? Do you have the capacity? And what would be the price of doing that?"

Mr. READDY. Just to be clear, the Russians have asked us to launch some of their elements, and we know what the Russians' launch capacity is with their Proton launch vehicle. Right now, the same repackaging would be required for their elements; they do not have robotic capability.

The unique things that the Shuttle provides have to do with the crew and robotic interface, the ability for the crewmen to actually pick up the modules and install them on the International Space Station. That is something that does not happen—it is not available in Russia, it is not available anywhere else in the world at this point.

It would have to be developed, at tremendous expense, and it would also take time. So we think that the nearest-term, quickest way to complete assembly of the International Space Station so that we can get on with the exploration agenda and learn those lessons that we need to, is to get the Shuttle back to flying again, in compliance with the Columbia Accident Investigation Board's report.

Senator BROWNBACK. I don't doubt that what you're saying is the quickest way to doing this. Nevertheless, I'm also curious about the safest and the least expensive to us, and I want to make sure we're inquiring about these other options. Because maybe it does extend the timeline out to completing ISS, but is there; the Shuttle's a very expensive program. We're committing, annually, in excess of somewhere between four to five billion dollars to the Shuttle program.

Mr. READDY. Yes, sir.

Senator BROWNBACK. We want to go to the Moon and Mars——

Mr. READDY. We do.

Senator BROWNBACK.—on human spaceflight. This is a huge stream of funds, and I want to make sure we've inquired of the Russians, the private sector, the European space community, and others about "Could you finish this? What would you do? How would you bid the proposal to do this?" so that we can see, as we're making these decisions now, that are going to determine the investment of $50 billion over the next 10 years, or whatever the case might be, that we're going the right route to finish this up.

Mr. READDY. Yes, sir.

Senator BROWNBACK.I'm not convinced that NASA has done that.

Mr. READDY. Well, sir, we will assess all the other capabilities and invite other people to make offerings with the alternative access to space in 2005 that we have planned. We have a budget line item that's $140 million. We will be looking for other opportunities to offload the Space Shuttle to the things that are not uniquely done—that require crew, that require robotic capability. And we will do that, sir.

Senator BROWNBACK. Does the United States have the option in the next few years for heavy lift from other areas? Lockheed have a heavy-lift capacity coming online in its Atlas V, that they're going to be testing in a year, is that correct?

Mr. READDY. Atlas V is flying. I think it's flown three times successfully, thus far, in a medium-lift capability. I think the Lockheed company will testify, on the second panel, as to what their plans are for the way ahead.

The only heavy-lift vehicle right now, besides the Titan IV, that exists, and is in service of the national defense right now for two remaining launches, is the Delta IV, which is planned for this fall.

Senator BROWNBACK. But Lockheed will have this online in a year or so? Additional heavy lift?

Mr. READDY.I'd like Lockheed to take the question, sir.

Senator BROWNBACK. All right.

Mr. READDY. I'm not familiar.

Senator BROWNBACK. And what's the weight of the largest station element left to launch? Do you know that?

Mr. READDY. I'll take that as a question, but a Shuttle's capacity to a Space Station orbit was 36,000 pounds. So that pretty much capped what each and every one of the launch packages had to be. But we'll get you the details of each and every one of the launch packages, so that you know what the number is, sir.

[John C. Karas of Lockheed Martin replied:]

Atlas V has many versions. The most powerful "medium/intermediate" class is the 500 series. (Even though this vehicle is classified as an intermediate, it has "heavy" lift capability. It has a -16 foot diameter and -55 foot long payload fairing (approximate shuttle cargo bay size equivalent) and can fly with 1 to 5 Solid Rocket Motors (SRM) strap-ons.

This vehicle version first flew on 7/12/03, and was 100 percent successful. This particular mission flew with 2 solids and has an equivalent of 28,700 lbs directly to ISS. This exact vehicle will fly a second time in Dec '04, with a commercial mission. This vehicle configuration, with 5 SRMs can lift 39,000 lbs to ISS. As a matter of fact, NASA "expendable LV and carriers directorate" has already bought this vehicle to fly the Pluto new horizons mission in Jan '06.

The other Atlas V we have is our "heavy" lift, or triple body. This vehicle has not yet flown, but is >95 percent common to our 500 series (identical Atlas liquid booster, Centaur upper stage, and 5.4m payload fairing). This vehicle could be ready to fly within 3 years of a request from any Government customer. We substitute SRMs for identical liquid boosters with unique attach hardware. This vehicle has 57,600 lb capability directly to ISS. These vehicles can lift -5–10 percent more if flown to lower ISS phasing orbits, where prox ops stages like ATV/HTV would operate.

Even though these vehicles have good lift and volume capability to ISS, there are still several items that have to be added and analyzed before they can assist in ISS assembly or servicing. These include: rendezvous and docking capability; STS equivalent payload attachments and environmental affects on existing ISS hardware; and impacts to planned human EVA and robotic arm assembly/servicing that would be different without an orbiter. These responses were jointly coordinated between Lockheed Martin and Associate Administrator, Bill Readdy before we both testified to Senator Brownback's appropriations subcommittee on May 5, 2004.

Lockheed Martin performed this type of payload conversion when DOD missions were taken off Shuttle and flown on Titans after *Challenger,* at a significant cost. In the case of the STS/ISS manifest, there may be some elements that are easier than others, but this detailed analysis has not been done.

Follow-Up Question: How much were these significant costs in converting the DOD payloads off the Shuttle and putting them on Titan after *Challenger*?

Lockheed Martin Response:

Significant costs were spent on each individual payload transitioned off Shuttle. Costs were in the hundreds of millions of dollars each on the payload side and on the launch vehicle side for analysis, modification and verification. This was tailored for and repeated for each classified and DOD payload. Less complex spacecraft, that had more flexible designs and were less integrated with the Shuttle, were easier to convert and cost less.

Therefore, even if the ELVs described had the necessary lift capability and developed the other required functions, complex ISS assembly missions still do not appear feasible to be flown on ELVs due to cost, schedule and risk factors. However, science and logistics type mission elements (within the 30 Shuttle mission manifest) appear feasible and should be studied further.

Senator BROWNBACK. I want to make sure that we're looking at this on an apples-to-apples basis, that if we've got so much weight that we need to get up to the Station, are there other alternatives that are coming on-stream that may not be owned by NASA—it may be by someplace else—can we do that, and at what cost?

Mr. READDY. Absolutely. Yes, sir.

Senator BROWNBACK. Are we getting that there? And that's why I'm trying to determine, you know, what's the weight and the capacity, what's the ability of others to be able to do. Now, there's a—being informed—didn't we take large payloads off the Shuttle in the 1980s, and start launching those on expendables? Didn't we, when we were——

Mr. READDY. NASA has always used a mixed-fleet approach for our scientific payloads. We've launched a number of scientific payloads and observatories and Department of Defense satellites on the Space Shuttle. We've also, of course, launched those on expendable launch vehicles, which we acquire. NASA has had a policy of acquiring those services from commercial sources, and continues this day. The Spirit and Opportunity that were just launched were commercially acquired. The Aura launch that is going to occur from Vandenberg next month is commercially acquired; that is a consistent pattern. We use a broad spectrum of launch vehicles, from Pegasus, at the low end, all the way up to, right now, what will be the Delta IV and the Atlas V launch-class vehicles.

Senator BROWNBACK. OK. You will be, then, inquiring specifically of the Russians and——

Mr. READDY. Yes, sir. We'll——

Senator BROWNBACK.—others about——

Mr. READDY.—we'll inquire from the Russians, the Europeans, and all our partners, as well as the private sector.

Senator BROWNBACK. Because before we move forward in the appropriation process this year, I would want that question asked and answered about what these other options are and at what price tag. And I realize these are big questions that take time to process, particularly when you're going to other groups, whether it's the Russians, the European Space Agency, or the private sector, you're going to need time to process the question that you put in front of them. But if we're investing this scale of money, if we're going back to the Shuttle that I continue to have questions about—this has been a great vehicle; it's done a lot of good. How much is it going to cost us to be able to get it flying again? And I don't know if you have a figure yet available on that——

Mr. READDY. No, sir, we don't.

Senator BROWNBACK.—of what it's going to cost to get the Shuttle back into space, back flying. Do we know that figure yet?

Mr. READDY. We could give you our 2005 budget submission, sir, and we're living within that. And we think that, currently, March to April next year is achievable. We're making steady progress toward that.

Senator BROWNBACK. That you will get it back into flight March or April next year?

Mr. READDY. Yes, sir. But we're being driven by the technical milestones along the way—this is not a schedule-driven exercise. You know, although there are launch windows that are driven by having to have a daylight launch, having to have the tank lit when we turn it loose when we get on-orbit, having to do inspection, and those kinds of things drive some very narrow windows for us to be able to launch. We'll move from one window to the next window as we solve the technical problems, but right now, the technical problems we have in front of us, we think, are solvable, and we're on track for a March to April window for next year.

Senator BROWNBACK. Do you think you're going to be able to stay within budget that you've budgeted for getting the Shuttle back in flight——

Mr. READDY. Yes, sir.

Senator BROWNBACK.—by March or April of next year? And you——

Mr. READDY. Yes, sir.

Senator BROWNBACK.—you don't see any glitches—none have presented themselves yet—to being able to do that within your current appropriation?

Mr. READDY. Within our current appropriation, no, sir. We don't see any issue at this point. But as time goes on, we're going to identify whatever technical issues arise, because in addition to the findings and recommendations of Columbia Accident Investigation Board, we have also raised the bar on ourselves. And a number of the things that we have found, like the rudder speed brake actuator corrosion, were things that NASA found. So we have raised the bar, in terms of our standard.

We've looked at this with a new lens, the space exploration division lens, such that we limit the Space Shuttle's life, not to 2020, but to just those missions that are essential for completing the

International Space Station, those missions that require the human, robotic, rendezvous, docking, those kinds of things here in the near term to complete the International Space Station.

So with that in mind, the re-certification that's going on right now for return to flight, has got a window that extends through International Space Station assembly complete.

Senator BROWNBACK. Good. I agree with you on doing this, not by a timeline, but on milestones; that you hit your milestones, rather than by a certain date. We don't want the Shuttle flying again if there are any safety questions that there remain about it at all.

Senator Nelson?

STATEMENT OF HON. BILL NELSON, U.S. SENATOR FROM FLORIDA

Senator NELSON. Thank you, Mr. Chairman.

Mr. Chairman, as you and I have discussed, both publicly and privately, the question, to me, is not whether or not we continue flying the Space Shuttle; the question is, how long do we continue flying the Space Shuttle, not only to get the Space Station completed, but long enough so that we do not have a down period between the end of the Space Shuttle and the beginning of flying of the crew exploration vehicle. That hiatus, under the time schedule laid out by NASA and the White House, could be as long as 4 years and, given the propensity for slowness of development of new, complicated, sophisticated systems, if it slips like the Space Shuttle did, which was supposed to fly in 1978 and did not fly until 1981, could be upwards of 7 years. And what I fear, from a policy standpoint, is that if we stop flying the Space Shuttle, and it's another 7 years before we have our own American vehicle of access to space by humans, that that puts us in the unenviable position of relying on Russian rockets. With the changes in international politics, with the changes that we've already seen as a result of September 11, how can we predict the vagaries of the Russian foreign policy projected now up until the year 2017? And I'm not sure that this country would want to rely just on Russian rockets, even if we flew the Space Shuttle until 2010.

But regardless of what I have just said—and I've said it many times, till I'm blue in the face—unless we can get the alarm bell sounded, get the sufficient will marshaled, to have the Space Shuttle flying safely to complete its mission, as outlined by NASA here, and to speed up the process of research and development and testing of a new vehicle, the United States of America is going to be put exactly in that position, with a hiatus of not being able to fly. That is what I think is going to threaten the interests of the United States in having assured access to space.

Now, take for example—you asked some very good questions about the ELVs. I came here from a markup in the Department of Defense authorization bill in our Senate Armed Services Committee. One of the issues in front of that Committee, which I think we're going to take care of, is that despite all the problems that Boeing has had with the ELV contracts, the resignation of top Boeing officials, and the penalties that Secretary Peter Teets has put upon Boeing, and so forth, there are plenty of us that, despite all of that, feel very strongly that you have to have two lines of ELVs, the Lockheed line, which, as Mr. Readdy said, is the new Atlas V, and then the Boeing line, which is the Delta IV. Why? Because if one of those went down, in this case, we wouldn't have assured access to space from unmanned vehicles. So that's an issue that you will confront later on, as we get on down. I think we're coming out of the Armed Services Committee supporting the position of two robust lines of EELVs. That's the bigger-lift ELVs of the future. Of course, the Atlas is already flying.

But then to say, if we've got that robust line, that you can suddenly take all of these components that have been designed and now built—and a lot of them are stored down at the Cape, ready for launch—and suddenly reconfigure them to put on the top of an ELV that is not man-rated, we're talking about a considerable bit of time, and a considerable bit of effort, and a considerable bit of cost.

And so I would submit to you that as we explore the policy questions, that, at some point in the future, I would ask you, as the Chairman of the Committee, for let's to focus—once we get through this policy question which you've raised, which is "Shuttle or no?"—and if that, as I hope, and I think it will be answered in the affirmative, yes to Shuttle, then the question is, "How long for Shuttle?" for the protection of the interest of access to space?

Since I've been in the Armed Services focus, I haven't heard all the things, but I assume the two witnesses have gone into the specifics on all the details of loads and design, and so forth and so on, about the reason for completing the Space Station. And I think, you know, the Space Shuttle is—it's a vehicle of risk. There's no doubt about it. You know, it was billed this last time as, like, one in 500. We now know that the catastrophic risk factor is two in 113. And yet mistakes were made that shouldn't have been made. And with the Gehman Commission report being implemented, it is, in my opinion, that we're going to be able to fly it as safe as possible, albeit still an element of risk. And any time that you're going to and from orbit, you're going to have some considerable risk.

And so I thank you for raising these issues. And if there's anything on the technical things that haven't raised, they need to be raised for the record here. And I wish you all would raise those.

Thank you.

Senator BROWNBACK. Thank you, Senator Nelson. I appreciate your thought, and I always appreciate your contributions here.

Of course, we're dependent on the Russians right now, so, I mean, those things do happen, and they're going to continue to happen.

Senator NELSON. And may I respond to that? Fortunately, we have the backup system. But that's with the Soyuz. And all Soyuz can do is carry three people, and not hardly any additional cargo. And then when Soyuz—or when the Progress comes up with cargo, it's carrying a very limited amount because of the size of that particular vehicle. To assemble the Space Station, you've got these huge components that are already built that are on the ground that have got to be launched. And so, for example, if you went just with the Russians, we can't put any more people up there on the Space Station than three, because we've got to have the capability, in case of an emergency, of getting the crew down. To utilize everything that we have built—not that we've completely assembled, but that we have built and hope to assemble—we need a lot more than three people on that Space Station.

Senator BROWNBACK. And that's what we're trying to assess, whether or not we have options in other places, and what price those would be.

Senator Breaux?

STATEMENT OF HON. JOHN B. BREAUX, U.S. SENATOR FROM LOUISIANA

Senator BREAUX. Are we in the question stage yet, or are we just chatting?

[Laughter.]

Senator BROWNBACK. I guess we're just chatting. No, we're in the question—they're in the question phase, and we've got another panel after this group.

Senator BREAUX. OK, well——

Senator BROWNBACK. If you want to hold for that or you can ask questions of these gentlemen.

Senator BREAUX. Well, thank you very much. I apologize, as we've all been voting and everything else.

And I share a great deal of the sentiment of the Senator from Florida with regard to the Shuttle. I mean, we've got to deal in reality here. I mean, it's nice to talk about future methods of getting into space—outer space, and taking care of the needs in future exploration, but in the short term and in the foreseeable future, we're going to be dealing with the Shuttle, and—at least I think so—and I would just hope that we can do everything to get it back on track as soon as we possibly can.

And I happen to have seen Sean O'Keefe in the hall, and we asked him a few questions before I came here, at lunchtime. And I was just wondering, can you give me, maybe, Mr. Readdy, an update on where we are down at Michoud, in New Orleans, with regard to some of the work that we're looking at after the Shuttle. I mean, I think we're doing some work down there on an unmanned—the possibility of moving to an unmanned type of vehicle to provide the carriage of hardware to Space Station and into outer space. Can you give me an update both on where we are with the Shuttle, and, second, where we are with the work that's being done at Michoud with regard to the unmanned vehicle?

Mr. READDY. Yes, sir. Well, first and foremost, we have to fix the insulation on the tank so that it doesn't come off. We have to make sure that we have ways to apply that insulation such that there is quality control, such that it will not come off.

Senator BREAUX. You're saying we have to do it, and we all agree with that. The question is, Are we doing it?

Mr. READDY. We are doing it, sir. And we conducted a review here just in the last couple of weeks. We're making great progress not only on application of the thermal insulation, but also doing non-destructive tests and evaluation of that to assure ourselves that we've done that.

We've also taken a look, through some very, very sophisticated computational fluid dynamics. This is like a wind tunnel that has no physical phenomena; it is all modeled in super-computers—and this allows us to take a model of the tank, and then see where little pieces of debris hypothetically could flow as the vehicle accelerates during ascent through the atmosphere. In addition, we have decided to peel back further around the side of the tank and institute new measures of applying the foam, so that none of that foam can transport itself to someplace where it could do damage to the orbiter.

Senator BREAUX. What about the unmanned rocket that they're doing some work on down there?

Mr. READDY. We have a number of trade studies that are underway to see what the way of the future is. Some of them include taking the expendable launch vehicles that we currently have in the inventory, and that are planned for future growth, into heavy-lift capacities to see how we could grow them even further. Some of the other trades include using Space Shuttle hardware, and being able to use that for an ultra-heavy lift capability. So those are all in the trade space that Admiral Steidle and his people are working on.

Senator BREAUX. Can you give me an update on the work of the Kistler operation down there? What are they doing?

Mr. READDY. The Kistler operation—we have thrown this wide open to a variety of proposals—not only commercial suggestions, but also in the private sector—and we had a competitive competition here; there were four proposals, which collapsed down to a single one. We went through the procedures and our procurement regulations and policies, and issued a justification for other than full and open competition because there was a single provider. I have to tell you that, at this moment, that procurement is under protest. The GAO is reviewing it, and I really can't comment much more on that matter at this point, sir.

Senator BREAUX. OK. Can you give us a time-frame on it, then, maybe about the——

Mr. READDY. We expect that this summer and we'll abide by the recommendations of the GAO.

Senator BREAUX. OK. Thank you.

[The prepared statement of Senator Breaux follows:]

PREPARED STATEMENT OF HON. JOHN B. BREAUX, U.S. SENATOR FROM LOUISIANA

There are lots of things we could talk about today: the timetable and justification of the President's Vision, what kinds of new technologies and vehicles we'll need to go to the Moon, the health of the U.S. Space Industry, the desperate need this Nation has to renew our launch systems and capabilities. That's what we should discuss today. Whether the Congress accepts the President's Vision or not, the health of the U.S. Space Industry is certainly an important and timely topic.

But if we're going to discuss doing away with the Shuttle—now, immediately—that changes the topic of today's discussion.

But that's a big step to assume we're going to take when we don't have any replacements for our current fleet of U.S. Space Shuttles and no means of getting to the next generation of crewed vehicles.

I personally can't foresee how we can say that we are renewing the U.S. Space Program if we also propose to stop everything we're doing, for a very long time, while we reengineer NASA from bottom to top. That's one way to renew the U.S. Space Program, but you'd be destroying it first.

That's just the wrong idea, it seems to me, and takes us further into a hole instead of helping us find our way out of it. We may not all like where the space program has taken us, but we're here and there's no easy answer to turning it around.

While it's true that if we were to start running down the path of shutting down the Shuttle and further limiting our commitment to the International Space Station, a number of issues are resolved. We wouldn't have trouble finding money to go back to the Moon. We could continue NASA science and aeronautics programs without interruption. And we be facing a future gap when we're flying U.S. astronauts aboard Russian space vehicles—we'd just be extending the gap we're in today.

Those seem like easy conclusions to come to. But while it may feel good to come to a much easier answer, I don't think it's the right answer. The Congress should not take any action that further jeapordizes the reputation and prestige of the United States in how it conducts its Space Program and how it honors its commitments to the International Community.

I think we need to come to agreement on what we're going to do, get our International Partners more involved in the discussion, and find out from industry and other U.S. space participants what can be done here. The President's Vision, as well intended as it might have been, hasn't stopped the discussion nor moved the country forward. I'm not sure what will move us forward from the current circumstance, short of spending a lot more on Space than this President and this Congress intends to spend. But we are in gridlock, and I hope we can find a way out of it.

Senator BROWNBACK. Thank you very much. I appreciate the panel, and I appreciate your input. I do want to hear back from you on some of the questions, and we'll pose those to you in writing, as well.

Mr. READDY. Yes, sir.

Senator BROWNBACK. The second panel, Mr. Mike Kahn, Vice President of Space Operations, ATK Thiokol; Dr. John Karas, Vice President of Space Exploration, Lockheed Martin; Mr. Robert Hickman, Director of Advanced Spacelift Force Application Directorate, the Aerospace Corporation; and Mr. Elon Musk, Chief Executive Officer, Space Exploration Technologies Group.

Thank you, gentlemen, for joining us.

[Pause.]

Senator BROWNBACK. Mr. Kahn, I believe we'll start with you. I'll need to vacate in about 30 minutes, so we're going to run the clock here at 5 minutes for each of you, if that would be acceptable. Mr. Kahn, we'll start with you. And if we could hear your testimony. Your full presentation will be put into the record, so you're free to summarize and make your major points that way.

Mr. Kahn?

STATEMENT OF MICHAEL KAHN, VICE PRESIDENT, SPACE OPERATIONS, ATK THIOKOL INC.

Mr. KAHN. Mr. Chairman and Members of the Committee, thank you for the invitation to appear before you and discuss future launch options for the Nation's human space program.

ATK applauds the President for articulating his vision for the Nation's exploration program, and fully supports its implementation. ATK is proud of its participation in the Space Shuttle program, and looks forward to our continued involvement in human and robotic missions.

Senator BROWNBACK. Could you get that microphone a little closer to you, would you, please?

Mr. KAHN. Thank you.

Senator BROWNBACK. Thanks.

Mr. KAHN. In my career, I've had the privilege to participate in many NASA programs, and I have experienced firsthand the excitement that comes with technical achievements and mission success. This success is what fuels our imagination, motivates us to advance technology, and gives us the confidence to meet future challenges.

There are three points I would like to cover on why the Space Shuttle system is so vital to continued human access to space, and how derivatives of this system can be the key enabler to achieve the objective of the space exploration vision.

The first step to achieve the space exploration vision is to continue the U.S. presence in space by returning the Shuttle to flight and completing construction of the International Space Station. We recognize the need to finish the Station, allowing space science to continue. The Shuttle is critical to completing the Station assembly, and we look forward to the Shuttle returning to flight as soon as it is safe to so do.

Second, we recognize the importance of the U.S. space policy that supports a mixed fleet of vehicles. Following this policy will maintain the integrity of the industrial base, and assure access to space. The unique capabilities of the existing fleet of Shuttle, EELVs, and commercial launch vehicles has served us well in the past, and may offer advantages where they can best serve exploration safely and affordably. The focus and resources for space exploration should be applied to building exploration capability and hardware that will be needed in order to travel to and function on the Moon and Mars, getting there and back, going beyond; not spent on something that can already be done, getting cargo and humans to low-Earth orbit.

Which really brings me to my third and primary point. We recognize there are numerous studies to put exploration payloads in orbit and assure they are affordable and sustainable. We are working with our industry partners to provide options that utilize the unique capabilities of a Shuttle infrastructure that can offer tremendous advantages.

By replacing the orbiter with a cargo-carrying module, and using select components of the Shuttle propulsion systems, a wide spectrum of capabilities that are sustainable and affordable can be offered—multiple missions, common hardware—most of which are already in place and flight-proven.

For heavy lift, by attaching a cargo carrier to the external tank and using some of the existing capabilities, like the booster's engines, launch pad, critical skills, we can have a heavy-launch payload, 150,000 pounds to orbit, which is three times the current capability. Since everything except the cargo carrier is already in operation, the cost to develop and fly the system is substantially reduced. In fact, this heavy-lift system could even start flying before the Shuttle program ends, sharing common hardware systems and people, which would make it even more cost effective.

In later years, if payload requirements grow and advantageous spiral development approach does exist to meet future needs, the flexibility is in place to use longer boosters, like the 5-segment motor tested last October, or a longer tank, which could put almost 200,000 pounds to orbit, or even an in-line configuration that could approach 225,000 pounds.

On a smaller scale, the crew exploration vehicle program plan shows demonstrator flights as early as 2008, with unmanned flights by 2011. And since this vehicle only weighs 35,000 to 40,000 pounds, heavy-lift configuration may not be required.

But in keeping with the approach of maximizing use of common infrastructure, common people, so costs and risks can be minimized, and safety and reliability maximized, a Shuttle-derived solution could also be considered. A human-rated, flight-proven CEV launch system can be available by simply utilizing a single booster with a liquid-engine second-stage. This configuration would use the same infrastructure—again, launch pad, people—as the heavy-lift system. Additionally, if there are 35,000 or 40,000 pounds of payload instead of the CEV, you could use the same system, further improving cost effectiveness.

By leveraging what has been invested in over the past 20 years in people, systems, production processing facilities, and the knowledge and experience gained on these human-rated elements, an exploration transportation system can be structured to minimize risk and cost while maximizing safety and reliability. Strong consideration should be given to an exploration transportation system that is derived from the experience-base and maximizes use of demonstrated common hardware. And by replacing the orbiter with a cargo carrier, operating costs can be reduced.

We recognize that EELV and commercial options are being reviewed, and know they can play a role; but for heavy lift and human lift, the demonstrated reliability and use of existing derived elements offer a low-risk and cost-effective approach.

The Shuttle program embodies a significant national resource of people—engineers, technicians, leaders—hardware facilities, and tooling. The program has benefited from the growing and learning that comes from human spaceflight. If this knowledge capability can be utilized, the drive for science and exploration can proceed with confidence, and minimize the cost and schedule impacts with a new system.

So, in summary, the Shuttle program not only plays a vital role in completing the Station and starting our progress toward exploration, but elements of this program may also serve as the building blocks for the exploration transportation system of tomorrow. The benefits of using these demonstrated, well-understood elements with common infrastructure across different exploration missions will give the program the foundation and confidence to meet the cost and schedule targets laid out by the President. In fact, the benefits to safety should not go without notice, either; not just because these systems were designed and maintained over the years to be man-rated, but the workforce in place today, supporting Space Shuttle, knowing their efforts will evolve, versus end, will be a tremendous motivation and source of security that will help enhance our focus on safety. Investments in the existing infrastructure will also have a better long-term utilization.

A propulsion system derived from Shuttle will allow maximum attention and resources to be applied to the challenging elements of exploration: living on the Moon, going to Mars, and things that have not been done. The elements of this propulsion system are already in operation, demonstrated, and fully capable to meet the safety, cost, and scheduled growth needs of tomorrow.

Thank you for the opportunity to share my thoughts with you. I'll be pleased to respond to your questions.

[The prepared statement of Mr. Kahn follows:]

PREPARED STATEMENT OF MICHAEL KAHN, VICE PRESIDENT, SPACE PROGRAMS, ATK THIOKOL INC.

Mr. Chairman and members of the Committee, thank you for the invitation to appear before you to discuss future launch options for the Nation's human space flight program. ATK applauds the President for articulating a vision for the Nation's space exploration program and fully supports its implementation. ATK is proud of its participation in the Space Shuttle program and looks forward to our continued involvement in human and robotic missions.

In my career I have had the privilege to participate in many NASA programs and have experienced first hand the excitement that comes with technical achievements and mission success. This success is what fuels our imagination, motivates us to advance technology and gives us confidence to meet future challenges.

There are three points I would like to cover on why the Space Shuttle system is vital to continued U.S. human access to space and why derivatives of this system can be the key enabler to achieve the objectives of the space exploration vision.

The first step to achieve the space exploration vision is to continue the U.S. presence in space by returning the Shuttle to flight and completing construction of the International Space Station (ISS). We recognize the need to finish the ISS, allowing space science to continue and enabling future human space science and exploration. The Space Shuttle is critical in completing the ISS assembly, and we look forward to returning the Shuttle to flight as soon as it is safe to do so.

Second, we recognize the importance of U.S. space policy that supports a mixed fleet of launch vehicles. Following this policy will maintain the integrity of the industrial base and assure access to space. The unique capabilities of the existing fleet of Shuttle, EELV's and commercial launch vehicles have served us well in the past, and may offer advantages where they can best serve exploration safely and affordably. The focus and the resources for space exploration should be applied to building exploration capability and hardware that will be needed in order to travel to and function on the Moon and Mars, getting there and back, and going beyond, not spent on something that already can be done—getting cargo and humans to low-Earth orbit. Which brings me to my third and primary point.

We recognize there are numerous studies on how to put exploration payloads (CEV or heavy) into orbit in an affordable and sustainable manner. We are working with our industry partners to provide options that utilize the unique capabilities of the Shuttle infrastructure. This can offer tremendous advantages. By replacing the orbiter with a cargo-carrying module and using components of the Shuttle propulsion system, a wide spectrum of capabilities that are sustainable and affordable can be offered; Multiple missions—common hardware. Most of which are already in place and flight proven.

For heavy lift, by attaching a cargo carrier to the external tank and using some of the existing capabilities, such as boosters, engines, launch pad, skills, etc.—we can launch a heavy payload—150K lbs to orbit, which is three times the current capability. Since everything except the cargo carrier is already in operation, the cost to develop and fly this system is substantially reduced. In fact, this heavy lift system could even start flying before the Shuttle program ends—sharing common hardware, systems, and trained people. This would make it even more cost effective.

In later years, if payload requirements grow, an advantageous spiral development approach exists to meet future needs. The flexibility is in place to use longer boosters like the 5-segment Shuttle motor tested last October, and a longer fuel tank to launch almost 200K lbs to orbit, or an in-line configuration that could approach 225K lbs.

On a smaller scale—the crew exploration vehicle program plan shows demonstrator flights as early as 2008, and unmanned vehicle flights by 2011. Since this vehicle will probably only weigh 35–40K lbs, the heavy lift configuration may not be required. In keeping with the approach of maximizing use of common hardware and proven infrastructure so costs and risks can be minimized, and safety and reliability maximized, a Shuttle-derived solution should also be considered.

A human rated and flight proven CEV launch system can be available by simply utilizing a single booster combined with a liquid engine second stage. This configuration would use the same infrastructure, launch pad and people as the heavy lift transportation system. Additionally, if there is a 35–40K lb payload/cargo requirement instead of the CEV, the same system could be used—further improving overall cost effectiveness.

By leveraging what has been invested over the past 20 years in people, systems, production and processing facilities, and also the knowledge and experience gained on these human rated elements an exploration transportation system can be structured that minimizes risk and cost, while maximizing safety and reliability. Strong consideration should be given to an exploration transportation system that is derived from this experience base, and maximizes use of demonstrated common hardware and infrastructure. And by replacing the orbiter with a cargo carrier or CEV, operating costs will be reduced. We recognize that EELV and commercial options are also being reviewed, and know they can play a role, but for heavy lift and human lift (CEV), the demonstrated reliability and use of existing Shuttle derived elements offer a low risk and cost effective approach.

The Shuttle program embodies a significant national resource of people (engineers, technicians, and leaders), hardware, facilities and tooling. The program has benefited from the growing and learning that comes with human space flight experience. If this knowledge and capability can be utilized, the drive for science and exploration can proceed with confidence and minimize the cost and schedule impacts that come with developing new launch systems.

In summary, the Shuttle program not only plays a vital role in completing the ISS and starting our progress toward exploration, but elements of the program may also serve as the building blocks for the exploration transportation system of tomorrow. The benefits of using these demonstrated, well understood elements, with common infrastructure across different exploration missions will give the program the foundation and confidence to meet the cost and schedule targets laid out by the President. In fact, the benefits to safety should not go without notice either—not just because these systems were designed and maintained over the years to be human-rated, but the workforce in place today supporting the Space Shuttle, knowing their efforts will evolve instead of end, will be a tremendous motivation and source of security that will only help to enhance the focus on safety. Investments in the existing infrastructure will also have better long-term utilization.

A propulsion system derived from the Shuttle will allow maximum attention and resources to be applied to the challenging elements of the exploration missions—living on the moon, going to Mars, and other things that have not been done. The elements of this propulsion system are already in operation, demonstrated, and fully capable to meet the safety, cost, schedule and growth needs of tomorrow.

Thank you for the opportunity to share my thoughts with you, I will be pleased to respond to any questions that you may have.

Senator BROWNBACK. I appreciate those thoughts, Mr. Kahn.

Dr. Karas?

STATEMENT OF JOHN KARAS, VICE PRESIDENT, SPACE EXPLORATION, LOCKHEED MARTIN

Dr. KARAS. Yes, sir.

Mr. Chairman, Members of the Subcommittee, distinguished panel members, thank you for the opportunity to appear before you to discuss U.S. launch-vehicle capabilities for meeting the vision of space exploration. We are truly excited about the journey the vision sets for our country, and I appreciate your leadership in moving this forward to realize this goal.

Mr. Chairman, Lockheed Martin is dedicated to each step of the vision—first, helping NASA successfully return to flight. We are working with Associate Administrator Bill Readdy in delivering improved hardware that supports the Shuttle from several operating units within the corporation, and we are also applying CAIB findings not only to Shuttle and the external tank, as well as other products within Lockheed Martin. We're also working closely with Admiral Steidle and his team to help define space-exploration architectures, which will ultimately drive all the space transportation elements, and specifically the heavy-lift requirements, for the future.

Lockheed Martin, in preparation for these studies, has several alternatives at work: one is being ELV-derived, one being Shuttle-derived, and clean-sheet vehicles. And everything that we're doing there is to trade those off as evenly as we can.

My written testimony is primarily focused on ELV, as requested. However, I believe each of these solutions is technically capable of evolving to meet the space-exploration heavy-lift requirements. The answer will be driven by two things: affordability and sustainability, or the nonrecurring and development costs of these systems, and the total mission manifest. That will include smaller robotic and scientific missions, larger CEV missions, ISS missions, and, potentially, DOD missions as an overall aggregate manifest.

Focusing now on ELVs, both the Atlas V and Delta IV ELVs—vehicles, in general, are very well prepared to evolve or spiral from today's capability. In the case of Atlas, we have introduced eight different models over the last 12 years, each successful on their maiden flights, each adding performance. Today's fleet of Atlas Vs can provide between 20,000 pounds and 60,000 pounds to low-Earth orbit. ELVs have not only increased in performance, but increased reliability and operability through new processes and new infrastructures. These infrastructures also have plenty of growth already built in. It is this proven, controlled-risk approach we've applied in the past that will apply to the future of the heavy-lift vehicle.

Atlas ELV has formulated a phased growth plan consisting of manageable risk and performance increments to match the potential range of needs. Utilizing new booster propulsion and the new ground airborne avionics and structures, all developed on ELV, we could increase tank size or number of engines, just like we did in earlier progressions, to grow to about 160,000 pounds to low-Earth orbit; we can do this in 25,000-pound increments. This range of vehicles also fit into the existing ELV operations and infrastructure as is today.

These configurations also have the benefit that each element can reach back to service existing commercial, civil, and DOD markets. We can strap more of these large boosters together and achieve over 200,000 pounds to low-Earth orbit. However, these vehicles call for ELV infrastructure changes and improved, more modern upper-stage engines with more thrust and reliability. It seems, at the upper end of the spectrum, whether you're talking about EELV, Shuttle-derived, or clean-sheet approaches, they all have similar performance-improvement needs and changes in their infrastructure.

In general, I believe there is an adequate number of solutions in the heavy-lift performance range to choose from.

As I mentioned before, the architectural requirements will define the mission model and the affordability level. These items will drive the answer to what's the correct heavy-lift, not so much the technology. Economics will dictate lower development costs with lower risk, minimizing overall infrastructure costs. And assuming super-heavy/flies-infrequently systems, with elements that can reach back into rate synergies or reach forward into other in-space transportation vehicles, will fare better than others.

Each option has pluses and minuses, and requires further study. So I recommend we don't really get ahead of ourselves yet, but work with Admiral Steidle and make sure we define requirements.

In that vein, we look forward to working with NASA and our industry partners in defining requirements and refining these trades.

Our goal is to attain a successful space transportation system, one that makes space exploration vision a reality.

Thank you.

[The prepared statement of Dr. Karas follows:]

PREPARED STATEMENT OF JOHN KARAS, VICE PRESIDENT, SPACE EXPLORATION, LOCKHEED MARTIN

Mr. Chairman and Members of the Subcommittee, I would like to thank you for this opportunity to appear before you to discuss U.S. launch capabilities for meeting the national vision for space exploration. We are truly excited about the journey that the vision sets for this country, and I appreciate your leadership in moving us forward to realize our vision.

Introduction

I am reminded of what Robert Heinlein wrote, *"Once you get to earth orbit, you're halfway to anywhere in the solar system."* As we were reminded by *Challenger,* getting to orbit is still risky; and as we were reminded by *Columbia,* coming home is still risky. It's the first and last 100 miles that are the hardest. As we move forward on this bold national vision for space exploration, we need to carefully learn and not repeat the lessons of almost 50 years of spaceflight. I would like to provide a few recommendations based on our experience and lessons learned.

First, as specified in the vision, our priority is to return the Space Shuttle to flight so that we can complete the International Space Station and regain our momentum and yes, confidence for human space exploration. I was honored to lead the Lockheed Martin Independent Review Team looking into the Space Shuttle External Tank. Lockheed Martin is supporting return to flight with all the necessary Corporate resources. We all must continue to incorporate the lessons and recommendations in the Columbia Accident Investigation Board report, not only for the Space Shuttle return to flight, but in everything that we do. For example, we are currently applying every applicable idea and recommendation in the CAIB report to the Atlas EELV launch system to make it even more reliable and robust. In keeping with the CAIB report, Lockheed Martin is also investigating alternative concepts and methods to assemble and service the Space Station in an attempt to reduce loss of crew risk.

Next, before we can adequately address the space transportation capabilities that will be needed for near-term or future space exploration, I have to stop and ask, "What are the requirements?" I've seen bold statements that we will need heavy lift approaching 50 to 100 tons to low-Earth orbit, yet the Space Exploration Level 1 requirements from NASA will not be available until September. Admiral Steidle and Code T are working diligently within NASA and with industry to establish these foundation requirements. I caution us not to get ahead of ourselves. How do we know whether existing launch vehicles will or will not satisfy our exploration needs for the next 20 years without understanding the exploration missions and requirements? We often like to jump to solutions, but it's not about heavy lift or developing new launch vehicles—it's not about the Niña, Pinta or Santa Maria (vessels to get there), it's about the affordability of the exploration mission.

In the early 1960s, we did not have existing launch vehicles going to space. A portion of the Apollo funding went into converting ICBMs to be space launch vehicles or developing a new Saturn V launch vehicle. Today, we are fortunate to have new launch capabilities through the EELV program. We are working with NASA to look at all options, as shown in Exhibit #1, in a systematic trade study, and keeping our options open until we have definitive requirements that will drive selection criteria and downselect to an optimal solution. These options include utilizing the EELV, Space Shuttle-derived, hybrid options, or a new clean sheet approach. All options are viable until we can perform adequate analysis based on the exploration requirements. The majority of my testimony focuses on EELV-derived vehicles per your request.

Existing EELV Capabilities

Another lesson that we can take from the 60s is that incremental, evolutionary development is critical. We did not get to the moon the first time by jumping directly to the Saturn V. We built, demonstrated, and learned on Mercury/Atlas to Gemini/Titan to Apollo/Saturn; it took us 68 unmanned launches and 20 human spaceflight launches before Neil Armstrong and Buzz Aldrin stepped onto the moon. We learned valuable lessons along the way at each incremental step, building capability and confidence for the next step. The Atlas V EELV today was built with that same model of evolutionary development from Atlas I, II, IIA, IIAS, III, to the family of Atlas V vehicles we have today, as depicted in Exhibit #2. Today, our Atlas V EELV covers a broad range of capabilities all of the way to approximately 65,000 lbs to low-Earth orbit, for government, commercial, and international customers at half the cost of just 10 years ago. At the same time, we have improved reliability through fault tolerance and parts count reductions and increased payload volume. In addition to vehicle improvements, we have drastically improved operations efficiency. We have created new infrastructure that doubles our flight rate, which is operated with reduced overhead cost, and increased responsiveness with demonstrated eight hours from vehicle on stand to launch.

Another lesson from the 60s that is critical for this program to be affordable and sustainable is NASA and DOD synergy. An Air Force ICBM called the Atlas was converted to the launch vehicle for the Mercury program to send John Glenn into orbit. The Air Force's larger ICBM called the Titan II was converted to the launch vehicle for the Gemini Program. While an Atlas ICBM is different from the human-rated space launch vehicle used for Mercury, they are fundamentally the same technology, and common processes, and provide economies of scale and utilization of the industrial base that benefited both NASA, the DOD, and the entire nation. When we move away from NASA–DOD synergy, as was demonstrated with the Saturn V and the Space Shuttle, one agency has difficulty maintaining an affordable and sustainable program. We have the opportunity again with a brand new fleet of advanced technology EELV launch vehicles to capitalize on investments by the DOD, Lockheed Martin, and Boeing, to once again have that synergy for mutual benefit. We have already studied improvements for human rating the Atlas V that will no doubt provide higher reliability and service for DOD and commercial customers. This is not unlike the improvements that we implemented in developing the Titan III for the Air Force, based on lessons from human rating the Titan II for NASA.

I also must mention a key lesson that we learned from *Challenger:* assured access to space. Access to space is no longer a luxury, but a necessity. This nation is dependent on our space assets. We need a robust system that has assured access in the event of a failure, so that we are not stranded without a launch capability for two years as we saw post-*Challenger* and now post-*Columbia.* Fortunately, the Atlas V and Delta IV EELV systems we have today are providing assured access to space with two very capable but independent systems.

Atlas Growth And Other Capabilities

When larger lift capability is required for extensive moon or Mars missions after 2015, the Atlas V will be able to meet the exploration requirements. As shown in Exhibit #3, with incremental steps from the current Atlas heavy, we can improve performance up to greater than Saturn V class lift. The first step is to expand our upper stage capabilities with larger tanks and existing propulsion. Both the Atlas V and Delta IV EELVs can get you to orbit; however, requirements will dictate that we go beyond Earth orbit. We would benefit from new in-space propulsion capabilities to efficiently break the bonds of Earth orbit. Unlike new booster engines that both Atlas and Delta have developed, more modern, larger upper stage thrust engines would enhance reliability and performance. We then can greatly improve our performance by just increasing the size of the booster fuel tanks and adding existing engines, not unlike when we developed the Redstone rocket, grew it to the Saturn I and, finally, the Saturn V rocket with common upper stage elements.

These vehicles up through 75 metric tons are compatible with today's existing EELV infrastructure. Further enhancements could be realized through partial reusability of the boosters, which are the easiest to recover. When I say partial reusability, I am referring to reusing only the most expensive elements, such as the engines and avionics with 3–5 uses. These methods date back to Saturn in the '60s and Atlas conducted experiments in the late 80s/early 90s to validate these concepts. If these concepts are implemented, recurring cost of less than $2,000 per pound could be achieved. This approach also minimizes development cost and performance impacts versus a fully reusable system.

As vehicle designs approach 100 metric tons or more, even larger stage elements become necessary, trending towards LO_2/RP boosters with LO_2/LH_2 core or second stages. This trend might suggest mixed fleet or hybrid combinations of EELV and Shuttle-derived elements, taking the best from each. This is analogous of how we combined the best elements of the Titan and Atlas launch vehicles to create the Atlas V. Also, we need to consider other technologies being developed within DARPA, like the Falcon Program, and other NASA and Air Force propulsion programs to provide the best solution within the space transportation, heavy lift trade space.

HLV Trade Study Drivers

Even though I have focused on the expendable launch vehicle capabilities, the methods and approaches described can be applied to Shuttle-derived or clean sheet solutions. Regardless of the solution, the key is not just meeting performance requirements but affordability and sustainability requirements as well. In order to meet those cost requirements, we must minimize the non-recurring costs while reducing and distributing overhead and infrastructure costs. Therefore, the larger-lift vehicle elements that fly infrequently must be synergistic with smaller higher-rate elements, such as CEV, ISS servicing, robotic exploration, and DOD missions. This common element approach is what enables the current EELV fleet to have cost effective, heavy class vehicles, unlike in the past where Titan, Atlas and Delta had independent hardware and infrastructures. Currently we have an abundance of credible solutions with existing technologies for heavy lift. After the exploration and overall space transportation requirements are defined, we can then complete the economic trade-offs.

The national vision for Space Exploration calls for international cooperation. We support this vision and believe it is important to enhance the sustainability and affordability of the Space Exploration vision. We have already implemented this model of international cooperation, not only on the International Space Station, but in the development of the Atlas V with the use of a rocket engine technology from Russia, payload fairing from Switzerland, and structures from Spain. We also have other business partnerships with Russian, European and Japanese companies that look forward to bringing their technology for space exploration.

In closing, our new expendable launch vehicles, Shuttle-derived, and clean sheet approaches can have the same or better capabilities by providing significantly more reliability than even their recent versions through continual improvements. However, no system will be perfect or invulnerable to failure. It would be negligent of us all to develop a launch system for space exploration that does not provide our astronauts a way out on a "bad day." The Mercury, Gemini, and Apollo systems all had crew escape systems. It is imperative that we maximize crew safety through continual improvements of launch vehicle reliabilities, institute integrated vehicle health management to warn us if something is going wrong, and deploy crew escape systems that are robust enough to protect our brave explorers.

Mr. Chairman, I would be happy to answer any questions you or Members of the Subcommittee may have. Thank you.

RESUMÉ OF JOHN C. KARAS, VICE PRESIDENT, SPACE EXPLORATION, LOCKHEED MARTIN SPACE SYSTEMS COMPANY

Joined Corporation in 1978
Appointed to Space Exploration position February 2004

John Karas is Vice President of Space Exploration for Lockheed Martin Space Systems Company. In this position, he is responsible for coordinating the corporation's capabilities and assets for human and robotic space exploration. Previously, he served as Vice President, Business Development, and was responsible for strategic planning, advanced technology concepts, and new business acquisition efforts for strategic and defensive missiles, and commercial, civil, and classified space lines of business. Karas reports directly to Tom Marsh, Executive Vice President, Lockheed Martin Space Systems Company.

Previously, Karas served as Vice President, Atlas and Advanced Space Transportation, for Lockheed Martin Space Systems. This responsibility included launch systems development and recurring operations for the Atlas program and advanced space transportation opportunities such as Orbital Space Plane and other manned, unmanned, reusable and expendable systems, including their respective business development, implementation and operations.

Karas served as Vice President and Deputy of the EELV/Atlas V organization from March 1997 to December 2002 and was responsible for developing new launch vehicles such as the Atlas IIIA, IIIB and Atlas V family, and their launch facilities.

Karas began his career with General Dynamics Space Systems Division in 1978 and joined Lockheed Martin in May 1994 when Lockheed Martin acquired the Space Systems Division. From 1995 to 1997, Karas served as program director for advanced Atlas launch vehicles, specifically the Atlas IIIA launch system. He was instrumental in the creation of the company's launch vehicle strategy, which included the evolution of the Atlas II, III and V family of launch vehicles.

Karas was Director of the Advanced Space Systems and Technology department and Site Director of the company's operations in Huntsville, Alabama from 1991 to

1995. In this position, he was responsible for management of operations research, system predesign, technology development and new business funds for the entire division. Under his direction, the department focused on structures and propulsion technology. For example, new materials (aluminum-lithium and composites) and manufacturing technologies (near-net forming) were matured for cryogenic tanks. New cryogenic feedlines and Russian engines and subsystems such as the initiation and development of RD–180, advanced Russian propellants and flange tests also were completed during propulsion technology development, all of which were successfully transitioned into production on the Atlas III, Atlas V and EELV programs. Karas was also responsible for Single Stage To Orbit and National Aerospace Plane cryogenic systems and contracted R&D.

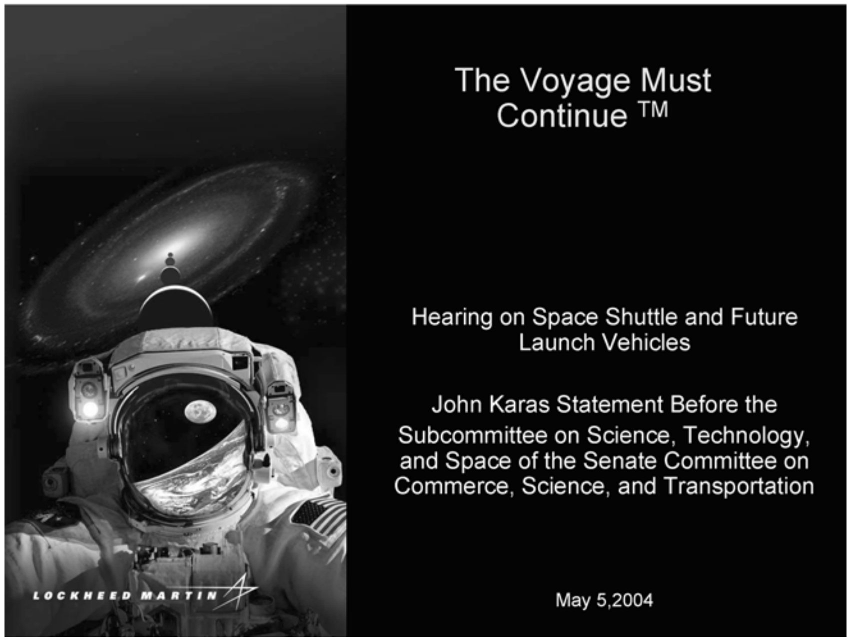
Karas served as Manager of Advanced Avionics Systems from 1986 to 1989. This group was responsible for new technology demonstration; conceptual predesign; avionics system design; and system integration lab testing for airborne guidance, navigation, and control (GN&C) functions. These new technologies included developments such as adaptive GN&C, multiple fault-tolerant controls, a totally electric vehicle using electromechanical actuators and artificial intelligence applications. The Advanced Avionics Systems group also had the responsibility for the development of independent and contract research and development (IR&D and CR&D) and insertion of new cost savings and performance enhancement technologies into existing products. During his tenure in this position, Karas was designated “Employee of the Year” for the development leading to the upgrade of the Atlas avionics system.

Prior to leading the advanced avionics department, Karas spent seven years working all levels of integration on the Shuttle-Centaur program. Karas led the integration of Centaur and associated airborne and ground support equipment with Shuttle Airborne, Ground Systems and Flight Operations. In this capacity, Karas became very familiar with reusable, manned systems and with operations at NASA's Johnson, Kennedy and Lewis Space Centers.

His technical expertise includes system definition, propulsion & avionic technology development and insertion, and hardware/software integration. Karas also has developed redundancy management concepts for several flight-critical systems and their associated system demonstration and validation techniques. Karas has served on several national and international committees on these subjects.

In 1987 Karas was named employee of the year for advanced avionics. Karas was one of five senior managers that received Aviation Week's 2000 Laureate Award for Aeronautics/Propulsion for development and integration of the RD–180 Russian engine with Lockheed Martin's Atlas launch vehicle. He was also named Lockheed Martin Astronautics Manager of the Year for 2000. Karas and the Atlas team were awarded the 2002 Lockheed Martin Space Systems Leadership Award for the on-cost and on-schedule successful first launch of EELV/Atlas V. Most recently, Karas received the Houston Rotary Stellar award for Atlas V and launch site in March 2004.

Karas received his bachelor's degree in Electrical Engineering from the Georgia Institute of Technology in 1978. While working toward his degree, Karas was a co-op student for four years where he worked for NASA at the Kennedy Space Center. Karas has taken advanced course work toward a master's degree in engineering and an MBA.


The Voyage Must Continue ™
Hearing on Space Shuttle and Future Launch Vehicles
John Karas Statement Before the Subcommittee on Science, Technology, and Space of the Senate Committee on Commerce, Science, and Transportation
May 5,2004
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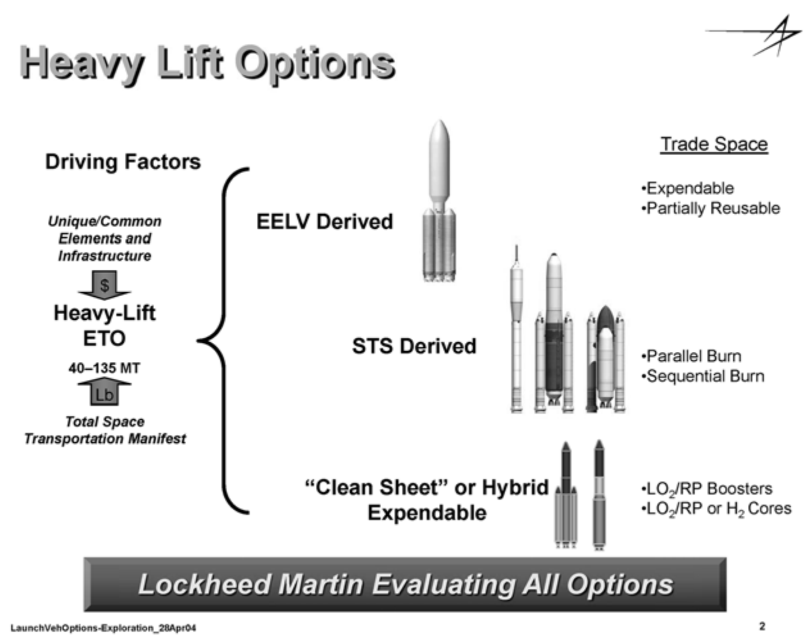
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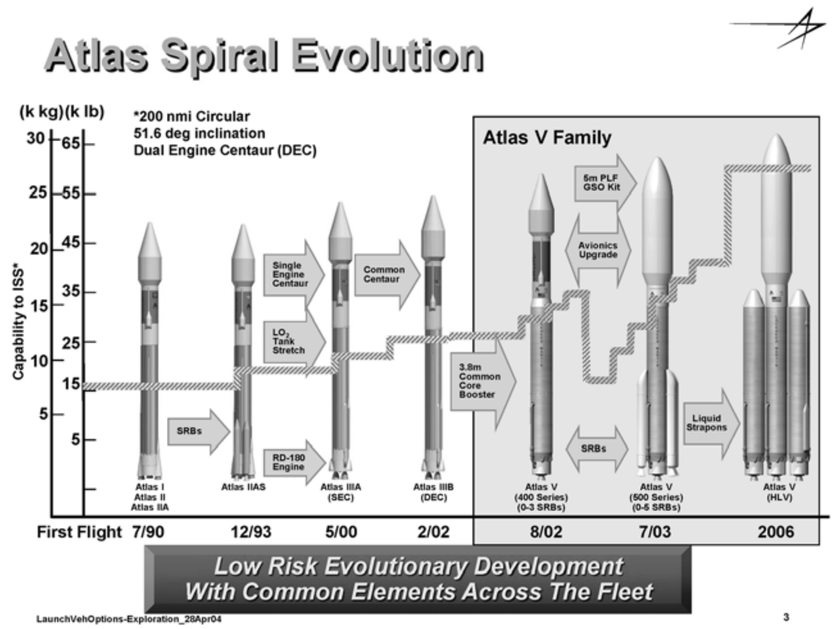
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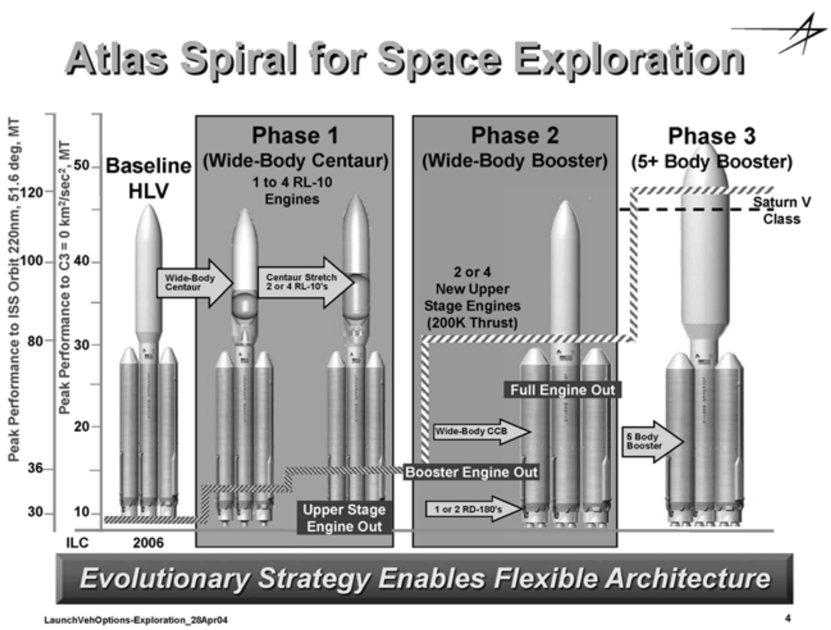
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Senator BROWNBACK. Thank you.
Mr. Hickman?

STATEMENT OF ROBERT A. HICKMAN, DIRECTOR, ADVANCED LAUNCH CONCEPTS, THE AEROSPACE CORPORATION

Mr. HICKMAN. Mr. Chairman, distinguished Committee Members, and staff, The Aerospace Corporation is a federally funded research and development corporation which supports the Air Force Space and Missile Center. For the past 44 years, we've helped the Air Force plan and develop launch systems.

I'd like to discuss recent aerospace studies that have got launch-system concepts that could support national needs.

While today's launch fleets are adequate to support current launch mission manifests, all sectors of the space community are seeking new transformational capabilities. The Air Force is planning tactical space missions to support warfighters in real time. These tactical payloads will weighs less than 10,000 pounds, and require very responsive and affordable launch systems.

From a civil perspective, the plan announced by the President to return to the Moon and eventually go to Mars is anticipated to need a very large launch vehicle with a lift capacity exceeding 100,000 pounds, and it would operate with a relatively low launch rate. To regain our competitive advantage, the United States commercial sector needs significantly lower launch costs in the 10,000- to 40,000-pound lift-capacity range.

In terms of launch-vehicle options, the current expendable launch vehicle range in price from $5,000 to $10,000 per pound. Significant decreases in the cost of medium- and heavy-lift launch are not anticipated. However, the Air Force and DARPA are engaged in a program known as FALCON to reduce the cost of small launch vehicles.

Reusable launch vehicles can potentially lower the cost by reusing flight hardware; but in the case of the Shuttle, that did not occur. Understanding the achievable operability of future reusable launch systems is crucial in determining their viability. Our detailed operability analysis indicates that, using current technologies, reusable launch vehicles can be developed which can be processed in 2 to 10 days. Even given this range of uncertainty and operability estimates, additional data is needed to determine if reusables have a clear cost advantage over expendable systems.

On the other hand, hybrid vehicles, consisting of a combination of a reusable first stage and expendable upper stages, provides a lower-risk alternative to achieve responsive and affordable space lift. They could potentially reduce the current launch cost by a factor of three, and achieve a routine churn time of 2 to 4 days. The hybrid vehicle requires only about a third of the amount of disposable hardware as an expendable system, and less than half of the hardware of a fully reusable system.

If you—in Figure 1 in the handout, it depicts the estimated manpower to process a hybrid, compared to the Space Shuttle, and the rationale to achieve a 26-hour churn time. Since a hybrid does not employ a reusable orbiter, it avoids the complexity and cost of a thermal protection system. Minimizing system complexity, eliminating toxic fluids, and incorporating modern long-life systems engines are a few of the potential enhancements to further reduce timelines and manpower. Many of these enhancements are also applicable to fully reusable systems.

We consider a hybrid a relatively low-risk first step in an evolutionary development process that provides incremental enhancements and capability over time. Developing separate launch systems for the defense, commercial, and civil community will be very costly. Modular vehicle designs that minimize the number and types of stages that need to be developed are one way to reduce the cost to support national needs.

The final figure is an example of a space-lift architecture capable of supporting a broad range of payloads. It's based on the derivatives of only two reusable vehicle elements. The first vehicle is a hybrid capable of launching 12,800 pounds to low-Earth orbit. If you combine this reusable stage with a larger reusable booster, the lift capacity increases to 25,000 pounds. Combining three of the larger stages increases total lift capability to 87,000 pounds. Finally, combining two of these larger boosters with the EELV common core increases lift capacity to 160,000 pounds.

In summary, the Aerospace study, in principle, indicates that a modular approach holds the promise of developing vehicles that could meet national needs. The reduced size of the engineering, logistics, and processing infrastructure, combined with the higher vehicle flight rate, will also minimize recurring cost.

This testimony was intended to provide the Committee insight into one potential design option, and it's not intended to be a recommendation for the development of systems supporting NASA or national needs. A lot further detailed study launch requirements have been defined are necessary to make that recommendation.

So I'd like to thank the Committee for the opportunity to describe some of The Aerospace Corporation advanced launch studies, and I stand ready to provide any further information or discussion the Committee may require.

[The prepared statement of Mr. Hickman follows:]

PREPARED STATEMENT OF ROBERT A. HICKMAN, DIRECTOR, ADVANCED LAUNCH CONCEPTS, THE AEROSPACE CORPORATION

Mr. Chairman, distinguished committee members and staff:

I am pleased to have the opportunity to describe the studies conducted by The Aerospace Corporation as they relate to advanced launch system design. The Aerospace Corporation is a private, nonprofit corporation, headquartered in El Segundo, California. s its primary activity, Aerospace operates a Federally Funded Research and Development Center (FFRDC) sponsored by the Under Secretary of the Air Force, and managed by the Space and Missile Systems Center (SMC) in El Segundo, California. Our principal tasks are systems planning, systems engineering, integration, flight readiness verification, operations support and anomaly resolution for the DOD, Air Force, and National Security Space systems.

For the past forty-four years Aerospace has helped the Air Force plan and develop launch systems. Recent studies performed by Aerospace have focused on advanced launch system concepts that could support the Defense Department, NASA, and the commercial sector. This includes involvement in joint studies where Aerospace worked closely with NASA and the Air Force to address launch system issues from a national perspective. The Advanced Space Lift Study began in 2002 and was the prelude to the Operationally Responsive Spacelift (ORS) Analysis of Alternatives (AoA). Aerospace performed the technical analysis for the ORS AoA that is intended to identify the acquisition strategy for future Department of Defense launch systems.

Desired System Capabilities

Today's launch fleet routinely deploys sophisticated spacecraft for navigation, communication, meteorology, intelligence, surveillance, reconnaissance, and space exploration.

Though impressive, today's launch fleet is not without limitations. Launch costs and preparation times limit space applications to a handful of high-value services. A revolution in new space applications is possible, but would require a new generation of launch systems to reduce cost and preparation times. The Department of Defense and NASA have expressed interest in such "transformational" capability; but before pursuing such a system, three major interrelated questions must be answered.

First, what capabilities are envisioned for the system? The goals of the defense, civil, and commercial space sectors are different, and the degree to which common solutions can be developed will determine whether separate or joint programs are pursued. Second, what sort of system should be designed? The choice between an expendable and reusable system, for example, will depend on whether design techniques and manufacturing technologies can be improved enough to make reusable systems operable and affordable. Third, what development strategy should be employed? The combination of risk tolerance, available budget, and time-frame of need will dictate whether developers seek radical advancements through aggressive technology projects or accept a safer, more incremental approach.

Defense Perspective

Defense launch systems are in the midst of a major transition. The heritage launch systems that served the Nation's needs for decades are now being retired and replaced by a new generation of launch vehicle families under the Air Force Evolved Expendable Launch Vehicle (EELV) program.

These vehicles are adequate to support the current mission manifest of national security satellites; however, the Air Force has identified a need to launch tactical space missions that support war fighters in real time. These missions would allow global strike capability, rapid augmentation of satellite constellations, rapid replacement of compromised space assets, deployment of specialized space vehicles for combat support, and wartime protection of American space assets. The Air Force is clearly considering that future military engagements may require the launch of large numbers of payloads in just a few days. The majority of these payloads are anticipated to be less than 10,000 lbs.

Prosecuting a war in this manner would be impossible without launch responsiveness. Through the Operationally Responsive Spacelift (ORS) Assessment of Alternatives, Aerospace is assisting the Air Force Space Command define its future launch system plans. At this point, the AoA is nearing completion.

Civil Perspective

In the course of more than 20 years, the Space Shuttle has launched more than 2 million pounds of cargo and sent more than 300 people into space. After the start of operations, however, it became increasingly clear that the shuttle was difficult to operate, maintain, and upgrade. Also, the differing orbiter configurations made each flight preparation a painstaking ordeal.

The Space Shuttle *Columbia* flew its 28th and final mission, launching on January 16, 2003, and breaking up 16 days later on its return to Earth. A new plan announced in early 2004 calls for a return to shuttle flights (until the International Space Station is completed) and development of a space vehicle capable of carrying a crew to the moon and beyond. Although no specific launch vehicle requirements have yet been defined, it is anticipated that a large launch vehicle will be needed with a lift capacity greater than 100,000 lb and with a relatively low launch rate.

Commercial Perspective

The traditional commercial launch market is focused principally on lofting communications spacecraft into Earth orbit. A methodology developed at Aerospace to explore launch costs suggests that the low flight rate required to support traditional communications spacecraft is not large enough, by itself, to justify large economic investments needed to achieve dramatically lower launch costs. To regain their competitive advantage, the U.S. commercial sector needs significantly lower launch cost for 10,000 to 40,000 lb. payloads.

Expendable Vehicles

Expendable launch vehicles could support responsive tactical space needs, just as ICBMs do, but the cost would be prohibitive. Current launch costs range from $5,000 to $10,000 per lb. of payload to low Earth orbit. The significant efforts of the EELV program have achieved moderate cost reductions, particularly for the heavy-lift vehicles, which use the same production line as the medium-lift versions. This commonality effectively provides the heavy-lift rocket with production rate advantages over the Titan IV and also permits the costs of engineering and logistics to be spread over a larger number of vehicles.

EELV has invested heavily in the latest manufacturing techniques and processes. Still, further significant decreases in medium or heavy lift expendable launch vehicle cost are not anticipated. On the other hand, small launch vehicles currently cost substantially more per pound of payload than their larger counterparts. The FALCOM program is a joint effort between the Air Force and DARPA to determine if a significant reduction in the cost of small expendable launch vehicles can be achieved.

Reusable Vehicles

Reusable launch vehicles are commonly proposed as responsive and inexpensive alternatives to expendable rockets. Analogies to aircraft systems suggest that reusing flight hardware should substantially reduce cost. However, in the case of the Space Shuttle this was not the case.

Understanding the achievable operability of future reusable launch vehicles is crucial in determining their viability. Aerospace developed the Operability Design Model specifically to evaluate maintenance, turnaround operations, and recurring cost as a function of launch system design. Using this tool, Aerospace evaluated the design features that control operability and determined that a new vehicle could improve operations by one to two orders of magnitude compared with the Space Shuttle simply by incorporating:

- Reduced vehicle complexity to reduce the number and type of components that must be serviced
- Increased design margins to provide a robust vehicle design with improved component life
- Improved accessibility and Line Replaceable Units (LRUs) to facilitate maintenance
- Modern thermal protection systems with 100 times the durability of Shuttle tiles
- Integrated Vehicle Health Monitoring to automate vehicle checkout
- Modern propulsions system designs with 10 times longer system life
- Non-toxic propellants that don't require hazardous processing
- Standardized practices and procedures for vehicle repair

Even with the industry's best operability analysis tools, experts agree that such estimates carry significant uncertainty. Credible estimates of turnaround time for the next reusable launch vehicle range from 2 to 10 days. This uncertainty is a problem for the Air Force because it will affect how many vehicles and facilities are needed to accommodate a surge in demand (for example, during wartime). This affects cost sufficiently that the difference between a 2-day and 10-day turnaround may determine the ultimate choice between expendable or reusable launch vehicles.

Estimates of reusable launch vehicle production cost are also uncertain because the only actual data point is the Space Shuttle. The per-pound cost to build each orbiter was twice that of the Air Force's most expensive aircraft, the B–2 bomber. Were this to hold true for the next reusable launch vehicle, production costs would severely limit its affordability. There are, however, rational arguments suggesting the cost will be lower. For example, the shuttle was the first of its kind, and was never optimized to control production cost. The orbiters have life-support systems, and must be built to safeguard the lives of the crew. The shuttle features distributed, rather than modular, subsystems. The shuttle program did not have access to the latest materials and production technologies. All of these problems can be corrected or minimized by using modern designs, technologies, and production techniques. Nonetheless, a factor-of-two uncertainty in production cost greatly affects the decision on expendable versus reusable launch vehicles.

According to Aerospace analyses, reusable launch vehicles that have been optimized for minimum dry mass have staging velocities (that is, the velocity at which the second stage deploys) roughly between Mach 10.5 and 11.5. In this case, the orbiter will be about half the dry mass of the booster. The mass of the reusable launch vehicle will grow steadily as the staging velocity deviates from this range. For example, if the staging velocity grows higher, the booster must be bigger to generate more thrust; if the staging velocity is lower, the upper stage will have to make up the difference to reach orbit. This is the problem faced by single-stage reusable launch vehicles. Single-stage vehicles are not practical without significant advancements in materials and propulsion technologies; however, two-stage vehicles are undeniably feasible, given the state of existing technologies.

Air-Breathing Reusable Vehicles

The appeal of air-breathing vehicles is that they get their oxidizer from the atmosphere, rather than carry it with them. Thus, they might, at least in theory, be smaller and less expensive than conventional rockets. The X–43A/C demonstrator programs represent crucial steps toward achieving an operational hypersonic capability. The recent successful proof-of-concept X–43A flight demonstration is an important and welcomed milestone. These demonstrations should provide a more credible foundation for predicting hypersonic vehicle performance, building upon, and hopefully, validating available CFD analyses and prior short duration wind tunnel tests. Many challenges remain before an operational capability can be achieved, particularly in the following areas of system operability over the complete mission flight regime:

- Propulsion
- Structures and materials
- Airframe aerodynamics and controls
- Thermal management

The Aerospace Corporation concurs with the space access development roadmap established by the NASA/Air Force Partnership Council in its assessment of hypersonic vehicles. A series of demonstrators increasing in scale and operational realism will allow for maturation of hypersonic technologies to an operational status. This development effort was estimated at about $24 billion (excluding the rocket-oriented efforts), requiring at least 15 years to complete. In this regard, we feel that hypersonic vehicles offer potential as a far-term solution but should be considered high risk.

Hybrid Vehicles

A hybrid vehicle consisting of a combination of a reusable booster with expendable upper provides a lower risk alternative to achieve responsive and affordable space lift. It could potentially reduce current launch costs by a factor of three and achieve a routine turnaround time of 2 to 4 days. Assuming optimal staging, at about Mach 7, the hybrid vehicle would only expend about one third as much hardware as a comparable expendable rocket. Thus, their recurring production costs are much lower. Also, the mass of the reusable booster stage for a hybrid is about 45 percent that of a fully reusable launch vehicle. Consequently, development and production costs are significantly less. For these reasons, even relatively low launch rates could economically justify their development.

The hybrid vehicle also carries less risk than a fully reusable launch vehicle primarily because it does not employ a reusable orbiter. Reusable orbiters present a difficult technical challenge, as they must survive on-orbit operations and reentry through Earth's atmosphere without significant damage. The reusable booster experiences a much less severe environment, resulting in fewer technical challenges and less risk.

Figure 1 depicts the estimated manpower to process a hybrid compared with the Space Shuttle and the rationale to achieve a 26-hour turnaround time.

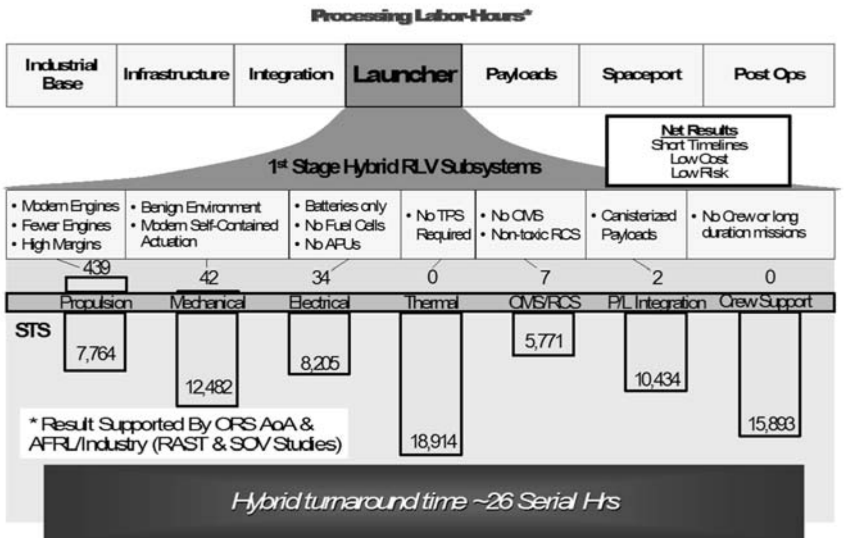

Figure 1. Comparison of Processing Manpower For Space Shuttle and Hybrid Vehicles

Designed with higher margins and vehicle health monitoring, the next generation of rocket engines is anticipated to have an operational life of 100 flights with a turn-time of 1–2 shifts. Electro-mechanical actuators and self-contained hydraulics can eliminate most of the time-consuming activities required to process the Shuttle hydraulic system. Batteries can replace complex fuel cells and auxiliary power units. The thermal environment for the hybrid's reusable booster would require minimal thermal protection systems. The booster would also have a limited need for reaction control systems that could be provided by gaseous reactants. Cannisterized payloads eliminate the need for payload bay reconfiguration between flights. The hybrid vehicle itself would not contain crew systems. Numerous other enhancements have been identified that give a hybrid vehicle a short 26-hour timeline. Many of these enhancement apply to both hybrids and full reusable systems, but due to the added complexity and the stressing thermal environment of an orbiter, reusables have longer processing timelines and with higher uncertainty and risk.

Development Strategy

While many development strategies have been considered over the years, the Air Force favors an evolutionary approach, focusing on incremental enhancements in capability. Flight tests of a demonstration vehicle are critical—to reduce uncertainties regarding achievable production cost and responsiveness, to supply information needed to crystallize a decision on an objective system, and to provide an affordable flight test bed to demonstrate design features and technologies needed to achieve various future technical objectives.

The hybrid is considered a relatively low-risk first step toward an operationally responsive spacelift capability, one with clear advantages over expendable and reusable launch vehicles. The performance of this hybrid will have far-reaching implications. If the cost and responsiveness of the reusable booster turn out to be on the low end of predictions, then the Air Force and NASA might decide to pursue a fully reusable launch vehicle as the next step. If not, then the hybrid configuration would still provide a cost effective solution.

Clearly, no first step in an evolutionary process can satisfy all the objectives of defense, civil, and commercial sectors. But the evolutionary approach establishes a low-risk process for building upon successes, ultimately supporting most or all spacelift needs. As they mature, this approach allows new technologies to be incorporated into the system to enhance system capability at low technical risk.

Modular Launch System Design

The initial cost of a new launch system for either DOD or NASA is relatively high. The combined cost of system development, facilities, and fleet procurement will reach well into the billions of dollars, even for small fleets. For this reason, it may be unaffordable to develop completely separate reusable launch vehicle designs for defense, commercial, and civil communities. By minimizing the number and type of stages that need to be developed, modular development approaches will probably be more affordable to pursue to support the needs of the DOD, civil and commercial community. For example, derivatives of boosters and orbiters could be used in various configurations to support a wide range of payload classes. While the derivatives would not be identical to the original vehicles, they would possess common systems and components, thus reducing development and production costs. This commonality would also reduce the operational costs of logistics and sustaining engineering, which are major recurring costs.

Figure 2 is an example of a notional spacelift architecture, designed by Aerospace to support a broad range of payloads, based on derivatives of only two vehicle elements. The first vehicle is a hybrid capable of launching 12,800 lbs to low earth orbit. Converting the hybrid's reusable booster to an obiter that is combined with a new larger booster generates a 25,000 lb. lift capacity. Combining two of these boosters with a third orbiter derivate increases lift capacity to 87,000 lbs. Finally using two of the larger booster with an EELV common core booster produces a super heavy lift capacity of 160,000 lbs.

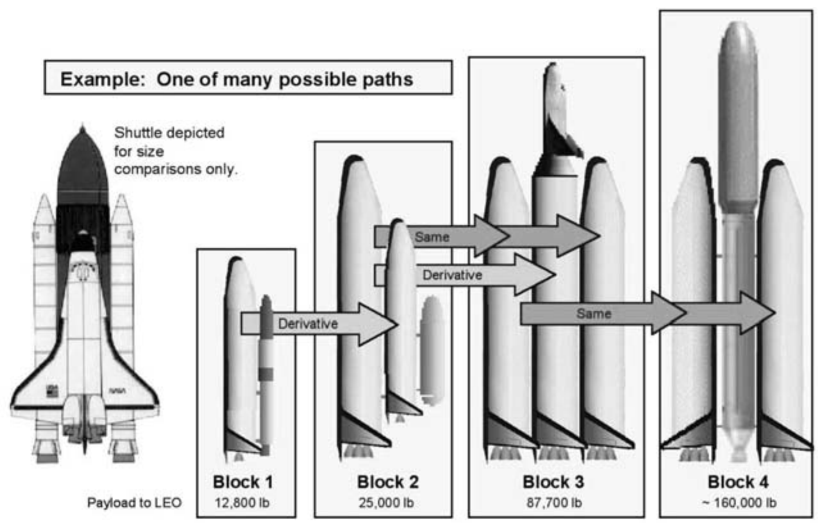

Figure 2. Modular Family of Vehicles—Based on Variants of 2 Reusable Stages

In closing, the ORS AoA recommends the Air Force pursue an advanced launch vehicle development strategy that incorporates an evolutionary development approach. The FALCON small launch vehicle program is the first step in that process. A hybrid vehicle represents the next logical step in developing larger more affordable and responsive reusable solutions. It can potentially lower the cost of space transportation by a factor of three. If successful, subsequent steps that may be fully reusable could further reduce the cost of space transportation. Modular vehicle designs can be developed that support all national needs at a lower cost than developing separate systems. The reduced size of the engineering, logistics, and processing infrastructure combined with a higher vehicle flight rate will also minimize recurring cost. The decision on which type of system to ultimately procure depends on numerous factors including specific performance objectives, funding availability, schedule requirements, and organizational priorities. Aerospace studies were only able to address a subset of these issues. This testimony was intended to provide the committee information and insight gained from analyses performed by Aerospace and does not constitute a recommendation for the development of systems supporting NASA or national needs.

Thank you for the opportunity to describe The Aerospace Corporation's advanced launch system studies.

I stand ready to provide any further data or discussions that the committee may require.

Senator BROWNBACK. Thank you, Mr. Hickman. I appreciate you doing that.

Senator BREAUX. Mr. Chairman?

Senator BROWNBACK. Yes?

Senator BREAUX. Prior to the time that Mr. Musk testifies, I'd like to make a comment, and I do so with utmost respect for the Committee and the Chairman. But I reviewed Mr. Musk's statement, a third of it deals with a protest, which he is financial involved in, about a contract with NASA. I asked the Administrator of NASA about the current contract that exists in this particular area, and he said that that contract award is currently under investigation by the General Accounting Office, and that he could not respond to what was going to happen with that until the inspection and the review by GAO is completed.

Mr. Musk has an interest in that outcome, and I think it's patently unfair to allow him to use this forum, without the other parties involved in that contract having an equal opportunity, at the same forum, to be heard to express their opinion of what is going on with regard to those contracts. It was very clear that NASA was unable to comment on it because it's under review.

And Mr. Musk's testimony—a third of which deals directly with that. I appreciate where he's coming from, but it's patently unfair to not have the other side present at the same forum, dealing with something that's under review by the government in a contract dispute.

Senator BROWNBACK. The reason the Committee had asked Mr. Musk to testify was on heavy-lift capacity. I mean, what we were trying to examine at the first of the hearing was Shuttle options, and the second portion of it here obviously is heavy-lift capacity. So maybe, Mr. Musk, if we could confine your comments to the issue of heavy-lift capacity, and not to the issue that's under review, would be an appropriate thing to do. And it's certainly not the Committee's desire to favor one group or another on anything. It's to try to get to some of the bottom of the factual settings that are taking place. So if that would be——

Senator BREAUX. I just want to say how much I appreciate the Chairman's position on it. I don't mind a complete discussion on the issue. That's an appropriate thing for the Committee to do, as long as we have all of the interested parties making the presentation. And I think your suggestion is very, very fair.

Senator BROWNBACK. If we could confine your oral presentation, Mr. Musk, to the issue that we're discussing here today, which is heavy-lift capacity and options to finish the ISS, I would appreciate that.

Mr. MUSK. Certainly. Although, it's worth correcting—I think Mr. Readdy misspoke when he said it was competitive. It was, in fact, not competitive, and that is the nature of the protest. So I just wanted to correct that reply.

Senator BROWNBACK. Let's just stay to heavy-lift capacity issues——

Mr. MUSK. Absolutely.

Senator BROWNBACK.—and finishing ISS, please.

STATEMENT OF ELON MUSK, CHAIRMAN AND CHIEF EXECUTIVE OFFICER, SPACE EXPLORATION TECHNOLOGIES (SPACEX)

Mr. MUSK. So, Mr. Chairman and Members of the Committee, thank you for inviting me to testify here today.

The past few decades have been a dark age for development of new human space transportation systems. One multibillion dollar government program after another has failed. In fact, they have failed even to reach the launch pad, let alone get to space. Those in the space industry, including some of my panel members, have felt the pain firsthand. The public, whose hard-earned money has gone to fund these developments, has felt it indirectly. The reaction of the public has been to care less and less about space, an apathy not intrinsic to a nation of explorers, but born of poor progress, of being disappointed time and again.

When America landed on the Moon, I believe we made a promise and gave people a dream. It seemed then that, given the normal course of technological evolution, someone who was not a billionaire—not an astronaut made of "the right stuff," but just a normal person—might one day see Earth from space. That dream is nothing but broken disappointment today. If we do not now take action different from the past, it will remain that way.

So what strategies are critical to the future of space launch vehicle development? And here my testimony, I think, will be a little different. First and foremost, I think we should increase and extend the use of prizes. This is a point whose importance cannot be overstated. If I can emphasize, underscore, and highlight one strategy for Congress, it is to offer prizes of meaningful scale and scope.

This is a proposition where the American taxpayer cannot lose. Unlike standard contracting, where failure is often perversely rewarded with more money, failure to win a prize costs us nothing. Offering substantial prizes for achievement in space could pay enormous dividends. We're beginning to see how powerful this can be by observing the X Prize, a prize for suborbital human transportation, which is on the verge of being won. It is a very effective use of money, as vastly more than the $10 million of prize money is being spent by dozens of teams that hope to win. At least as important, however, is the spirit and vigor it has injected into the space industry and the public-at-large. It is currently the sole ember of hope that 1 day they, too, may travel to space.

Beyond space, as the Committee is no doubt aware, history is replete with examples of prizes spurring great achievements, such as the Orteig prize for crossing the Atlantic nonstop by plane, and the Longitude Prize for ocean navigation.

Few things stoke the fires of creativity and ingenuity more than competing for a prize in fair and open competition. The result is an efficient Darwinian exercise with the subjectivity and error of proposal evaluation removed. The best means of solving the problem will be found, and that solution may be in a way and from a company that no one ever expected.

One interesting option, although radical, might be to parallel every major NASA contract with a price valued at one-tenth of the contract amount. If another company achieves all of the contract goals first, they receive the prize and the main contract is canceled, but the objective achieved. At minimum, it will serve as a spur for whoever does win the main contract.

Some people believe that no serious company would pursue a prize; this is simply beside the point. If a prize is not won, it costs us nothing. Put prizes out there, make them of meaningful size, and many companies will vie to win, particularly if there are a series of prizes of successively greater difficulty and value. I recommend strongly supporting, and actually substantially expanding up, the proposed Centennial prizes put forward in the recent NASA budget. No dollars spent on space research will yield greater value for the American people than those prizes.

Second, I think we should rigorously examine how any proposed new vehicle will improve the cost of access to space rigorously. The obvious barrier to human exploration beyond low-Earth orbit is the cost of access to space. This problem of affordability dwarfs all others. I do not think there are multiple problems in space; I think there is one, and that is the cost of access to space.

If we do not set ourselves on the track to solving it with a constantly improving price-per-pound to orbit, in effect, a Moore's Law of space, neither the average American, nor their great-great-grandchildren will ever see another planet. We will be forever confined to Earth, and may never come to understand the true nature and wonder of the universe. So it is critical that we thoroughly examine the probable cost of alternatives to replacing the Shuttle before embarking upon a new development. The Shuttle today costs about a factor of ten more per flight than originally projected. We do not want to be in a similar situation with its replacement.

In fact, it was precisely to improve the cost and reliability of access to space—initially for satellites, and later for humans—that I established SpaceX, although some of my friends still think the real goal was turn a large fortune into a small one.

Our first offering, called Falcon I, will be the world's only semi-reusable orbital rocket, apart from the Space Shuttle. In fact, we employ a reusable first stage and an expendable upper stage, as Aerospace Corporation recommends as the smart approach to improving cost. So although Falcon I is a light-class launch vehicle, we have already announced and sold the first flight of Falcon V, our medium-class rocket.

Long-term plans called for development of a heavy-lift, and even a super-heavy, if there was customer demand. We expect that each size increase would result in a meaningful decrease of cost-per-pound to orbit. For example, dollar-cost-per-pound to orbit dropped from $4,000 to $1,300 between Falcon I and Falcon V. Ultimately, I believe $500-per-pound or less is very achievable.

Item 3 was ensuring fairness in contracting, but I will stop there.

[The prepared statement of Mr. Musk follows:]

PREPARED STATEMENT OF ELON MUSK, CHAIRMAN, CEO OF SPACE EXPLORATION TECHNOLOGIES CORP. (SPACEX)

Mr. Chairman and Members of the Committee, thank you for inviting me to testify today on the future of Space Launch Vehicles and what role the private sector might play.

The past few decades have been a dark age for development of a new human space transportation system. One multi-billion dollar Government program after another has failed. In fact, they have failed even to reach the launch pad, let alone get to space. Those in the space industry, including some of my panel members, have felt the pain first hand. The public, whose hard earned money has gone to fund these developments, has felt it indirectly.

The reaction of the public has been to care less and less about space, an apathy not intrinsic to a nation of explorers, but born of poor progress, of being disappointed time and again. When America landed on the Moon, I believe we made a promise and gave people a dream. It seemed then that, given the normal course of technological evolution, someone who was not a billionaire, not an astronaut made of "The Right Stuff", but just a normal person, might one day see Earth from space. That dream is nothing but broken disappointment today. If we do not now take action *different* from the past, it will remain that way.

What strategies are critical to the future of space launch vehicles?

1. Increase and Extend the Use of Prizes

This is a point whose importance cannot be overstated. If I can emphasize, underscore and highlight one strategy for Congress, it is to offer prizes of meaningful scale and scope. This is a proposition where the American taxpayer cannot lose. Unlike standard contracting, where failure is often perversely rewarded with more money, failure to win a prize costs us nothing.

Offering substantial prizes for achievement in space could pay enormous dividends. We are beginning to see how powerful this can be by observing the X Prize, a prize for suborbital human transportation, which is on the verge of being won. It is a very effective use of money, as vastly more than the $10 million prize is being spent by the dozens of teams that hope to win. At least as important, however, is the spirit and vigor it has injected into the space industry and the public at large. It is currently the sole ember of hope that one day they too may travel to space.

Beyond space, as the Committee is no doubt aware, history is replete with examples of prizes spurring great achievements, such as the Orteig Prize for crossing the Atlantic nonstop by plane and the Longitude prize for ocean navigation.

Few things stoke the fires of creativity and ingenuity more than competing for a prize in fair and open competition. The result is an efficient Darwinian exercise with the subjectivity and error of proposal evaluation removed. The best means of solving the problem will be found and that solution may be in a way and from a company that no-one ever expected.

One interesting option might be to parallel every major NASA contract award with a prize valued at one tenth of the contract amount. If another company achieves all of the contract goals first, they receive the prize and the main contract is cancelled. At minimum, it will serve as competitive spur for cost plus contractors.

Some people believe that no serious company would pursue a prize. This is simply beside the point: if a prize is not won, it costs us nothing. Put prizes out there, make them of a meaningful size, and many companies will vie to win, particularly if there are a series of prizes of successively greater difficulty and value.

I recommend strongly supporting and actually substantially expanding upon the proposed Centennial Prizes put forward in the recent NASA budget. No dollar spent on space research will yield greater value for the American people than those prizes.

2. Rigorously Examine How Any Proposed New Vehicle Will Improve the Cost of Access to Space

The obvious barrier to human exploration beyond low Earth orbit is the cost of access to space. This problem of affordability dwarf's all others. If we do not set ourselves on the track of solving it with a constantly improving price per pound to orbit, in effect a Moore's law of space, neither the average American nor their great-great-grandchildren will ever see another planet. We will be forever confined to Earth and may never come to understand the true nature and wonder of the Universe. So it is critical that we thoroughly examine the probable cost of alternatives to replacing the Shuttle before embarking upon a new development. The Shuttle today costs about a factor of ten more per flight than originally projected and we don't want to be in a similar situation with its replacement.

In fact, it was precisely to improve the cost and reliability of access to space, initially for satellites and later for humans, that I established SpaceX (although some of my friends still think the real goal was to turn a large fortune into a small one). Our first offering, called Falcon I, will be the world's only semi-reusable orbital rocket apart from the Space Shuttle. Although Falcon I is a light class launch vehicle, we have already announced and sold the first flight of Falcon V, our medium class rocket. Long term plans call for development of a heavy lift product and even a super-heavy, if there is customer demand. We expect that each size increase would result in a meaningful decrease in cost per pound to orbit. For example, dollar cost per pound to orbit dropped from $4,000 to $1,300 between Falcon I and Falcon V. Ultimately, I believe $500 per pound or less is very achievable.

3. Ensure Fairness in Contracting

It is critical that the Government acts and is perceived to act fairly in its award of contracts. Failure to do so will have an extremely negative effect, not just on the particular company treated unfairly, but on all private capital considering entering the space launch business.

SpaceX has directly experienced this problem with the contract recently offered to Kistler Aerospace by NASA and it is worth drilling into this as a case example. Before going further, let me make clear that I and the rest of SpaceX have a high regard for NASA as a whole and have many friends & supporters within the organization. Although we are against this particular contract and believe it does not support a healthy future for American space exploration, this should be viewed as an isolated difference of opinion. As mentioned earlier, for example, we are very much in favor of the NASA Centennial Prize initiative.

For background, the approximately quarter billion dollars involved in the Kistler contract would be awarded primarily for flight demonstrations & technology showing the potential to resupply the Space Station and possibly for transportation of astronauts.

That all sounds well and good. The reason SpaceX is opposing the contract and asking the General Accounting Office to put this under the microscope is that it was awarded on a sole source, uncompeted basis to Kistler instead of undergoing a full, fair and open competition. SpaceX and other companies (Lockheed and Spacehab also raised objections) *should have, but were denied* the opportunity to compete on a level playing field to best serve the American taxpayer. Please not that this is a case where SpaceX is only asking for a fair shot to meet the objectives, not demanding to win the contract.

The sole source award to Kistler is mystifying given that the company has been bankrupt since July of last year, demonstrating less than stellar business execution (if a pun is permitted). Moreover, Kistler intends to launch from Australia using all Russian engines, raising some question as to why this warrants expenditure of American tax dollars.

Now, although we feel strongly to the contrary, it is possible that NASA has made the right decision in this case. However, does awarding a sole source contract to a bankrupt company over the objections of others *sound* like a fair decision? Common sense suggests the answer. Whether Kistler does or does not ultimately deserve to win this contract, it should never have been awarded without full competition.

Again, thank you for inviting me to testify before you today.

Senator BROWNBACK. Thank you very much.

Gentlemen, thank you very much for the testimony.

The first three gentlemen, you all three identified significant options for heavy-lift capacity that are currently available. Mr. Kahn, you were saying, let's use the Shuttle-engine portions of this when we can—we can reconfigure, use that, that that's a proven system, and that you can get—what would you say—what were you saying the lift capacity you could get up to in using that—150,000?

Mr. KAHN. 150,000.

Senator BROWNBACK. What's that?

Mr. KAHN. 150,000.

Senator BROWNBACK. 150,000?

And, Dr. Karas, you were saying you could get up to 200,000 pounds in a lift capacity?

Dr. KARAS. You could, but I think—apples-to-apples, it's about 150,000 pounds, as well, in the near term.

Senator BROWNBACK. In the near term. What do you mean by "near term"?

Dr. KARAS. Within the technology and infrastructure we have today, 3 to 5 years.

Senator BROWNBACK. Mr. Kahn, what's your time-frame to be able to do what you're talking about, of lift capacity using Shuttle——

Mr. KAHN. Well, the——

Senator BROWNBACK.—technology?

Mr. KAHN.—propulsion part of the lift capacity, which is the boosters and the tank and the engines, are already flying today, so they exist. So it's just, How long does it take to build a cargo carrier and bolt it onto the tank, instead of bolting on the orbiter?

Senator BROWNBACK. Any idea on that, of a cargo carrier, of what it would take to do?

Mr. KAHN. It's probably in the order of 3 to 5 years, as well.

Senator BROWNBACK. To get that pulled together?

Mr. Hickman, in your approach you're talking about 160,000 pounds lift capacity, is that correct?

Mr. HICKMAN. That's correct.

Senator BROWNBACK. OK. And what's the time-frame of your development to do something like that, along the lines of what you've described?

Mr. HICKMAN. Well, we propose more of an evolutionary approach to get there——

Senator BROWNBACK. Just get that microphone up a little closer.

Mr. HICKMAN. We propose more of an evolutionary approach to get there, starting off with smaller payloads and lift vehicles, and growing to the larger ones. I think one of the things that it's important to emphasize, that we weren't just trying to achieve a specific lift capacity, but the transformational capabilities that most of the sectors need also depend on responsiveness and significantly lower cost; so we looked at hybrid and reusable vehicles to do that. And we think they're really not limited by technology, currently, but by available funding. With a well-funded program, I think the time frame to get to heavy lift would be in the eight to ten-year time frame.

Senator BROWNBACK. Eight to ten-year to get there.

Gentlemen, why is it so costly for us? We've been at this now five decades, to get into space. We're costing—Shuttle is a four-billion-plus annual program, whether it flies or not—you know, a billion dollars a shot. I mean, this is difficult, but it's extraordinarily expensive. Can you tell me why this has remained so expensive and over the lines of what we thought it would be at this point in time?

Mr. HICKMAN. I'll try to address that question, if I may. Currently, in our ORS AoA study, which we did for the military to look at their——

Senator BROWNBACK. Get that microphone up closer, will you please?

Mr. HICKMAN. In the AoA, the analysis of alternatives, that we performed for the military, we looked at a large number of costs for aerospace systems across the board—aircraft, missiles, cruise missiles, ballistic missiles. They all seemed to have a floor of about $750 a pound, is what it basically costs to make fairly sophisticated hardware. We did not see that we'd get significantly below that floor unless you move toward reusable systems. And so we think that one of the key things, though, is to design those systems to be operable from the outset. The Shuttle was not designed with the factors necessary to make it operable. We believe, with a highly focused program, focused on operability, and the proper use of reusability—and we think that's in the hardware of the first stage—that you can get down to a factor-of-three reduction in cost over what we're seeing today.

Dr. KARAS. Mr. Chairman, I'd like to respond. I think the Shuttle is a wonderful machine and has a lot of capabilities that expendables don't, like cargo-down. So I think those are other factors that drive cost.

I think in the case of ELV, or if we take Atlas specifically, as I mentioned, we've phased in many vehicles. Every time we had a different vehicle phase-in, we improved reliability and performance. In the competitive environment—it's kind of hard in an open environment to go, quote, "cost," but I think in my paper I stated that you can buy vehicles for significantly cheaper than the $6,000 per pound today. It's probably two or three times less that, off the shelf. And I think we can get the dollars a pound that are in the $2,000 to 1.5—$1,500 a pound, relatively easily using the scales of economy that we've talked about.

So I think you can probably draw a line through at least through Atlas and the last 10 years of constant progression of dollar per pound coming down. So I think there are areas where we have done that. We have a long way to go. But I think it's significantly less than the Shuttle because of the different driving requirements.

Senator BROWNBACK. Would that auger for—that we need to move away from the Shuttle as fast as possible to other type of lift capacity to finish ISS?

Dr. KARAS. I think Bill Readdy put it best, where it's all about the requirements. And I think there are heavy-lift requirements that can have the payload capacity, both volumetrically and weight-wise, to put cargo to Station. But it's all the other things that expendables don't have today, like rendezvous and dock, human interfaces, robotics, to be able to service the Station.

So there are different requirements, and we are working with NASA in studies to go evaluate those things for them. But I think in the near term, it would be hard to go do that because of the capacity that the expendables don't have.

Senator BROWNBACK. And the other areas that they don't have.

Mr. Musk, what's a meaningful prize? What's the size of a meaningful prize to get people to do some of the things that we would like to see private sector engage in, in space?

Mr. MUSK. I think you can get very meaningful outcomes for dollar figures in the tens of millions. And certainly, I think, for something like $100 million for repeating the John Glenn flight has been suggested. I think that is eminently doable. In fact, I would say—here's a good way to approach something: If you get an estimate, whatever the NASA estimate is to get something done, erase a zero and make that a prize. And I think you will find that it is done for that amount of money.

Senator BROWNBACK. Gentlemen, I have another hearing I need to go to. I appreciate very much you coming in, providing your expertise and your thoughtfulness, the written testimony, as well. Thank you so much.

The hearing's adjourned.

[Whereupon, at 4:25 p.m., the hearing was adjourned.]

APPENDIX

PREPARED STATEMENT OF HON. ERNEST F. HOLLINGS, U.S. SENATOR FROM SOUTH CAROLINA

As the Congress evaluates the President's proposal to return to the Moon by the end of the next decade, our focus has turned to the Gordian Knot at its heart. Since there is no new money for this effort, we have an extremely tight schedule built on many interwoven, complex changes to the U.S. Space Program. All of these changes must unfold in neat, sequential order without any hiccups in order for the proposal to succeed.

The plan assumes NASA will stop flying the Shuttle on a date certain, transferring its funds to the new Exploration Program, and that NASA eventually end U.S. participation in the International Space Station so that funding for the campaign to settle the Moon can start in earnest. The President's schedule, and proposed funding, is such that any upset in one part of the timetable will upset another part. Therefore, even the rather casual deadline of 2020 may be hard to accomplish unless everything goes just right.

And there are a couple of additional flies in this ointment. NASA has proposed that many laudable NASA science programs should be delayed, deemphasized, and probably cancelled in order to put this new Vision in place. NASA has also proposed that for some time, presumably from 2010 to 2014, there will be no Shuttle and no U.S. replacement vehicle to fly U.S. crew to and back from the Space Station. I think it's unlikely that this or any future Congress is going to go along with those parts of this plan. But both of these assumptions are also key to making this plan work within the resources the President has assigned to the Vision.

So here we have the Gordian Knot—you probably can't execute the timetable as it's proposed, but when you look for how you might change it in order to either keep it on schedule or even accelerate it, you come to very hard choices.

That's part of what this hearing is going to discuss today—how do we move forward to renew and reenergize the U.S. Space Program, but not bring it to collapse and confusion by introducing interruptions that might threaten to put the program into further chaos.

As I said in my statement on April 1, "You can't sustain commitment to the U.S. Space Program by shutting it down, and you can't accelerate development while you are in a sustained lull." I stand by those words again today. You can't slow down and you can't speed up and make the President's Vision work, not without a lot more funding and a very different way of doing business than we have in the past.

There are some who want to discuss "scuttling the Shuttle". But there is much at stake in these discussions that a simple phrase does not capture, including American lives on board an orbiting space laboratory. At the end of this discussion, let's be clear that whatever vision or space mission the U.S. chooses to conduct in the future, it must be done safely and with emphasis on reducing human risk, not extending it needlessly. So we need to be careful to not get so bollixed up in schedules and assumptions and new plans that we turn the President's Vision into something that adds risk to Human Space Flight instead of decreasing it.

I don't know what the answer is, but we need a whole lot more answers and discussion than we've heard to date. My fear is that today's hearing and others like it are going to start taking us in the wrong direction, into more confusion than clarity. That's one reason why the President's Vision concerns me; in this year of tragedy in the American Space Flight Program, we need to be wholly focused on putting the U.S. program firmly on its feet and cautious about any vision that takes us in any other direction. Let's focus on adding prestige and integrity to our U.S. Space Flight program, not cause for further uncertainty and alarm.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN MCCAIN TO WILLIAM F. READDY

Question 1. What infrastructure improvements will be needed to support the increased Space Shuttle flight rate to complete the International Space Station (ISS)?

Answer. The planned flight rate does not necessitate physical infrastructure improvements. Maintenance associated with sustaining the existing infrastructure will be required. Additionally, irrespective of the flight rate, NASA is making improvements to our management processes and human capital infrastructure in response to the CAIB report recommendations, including the establishment of an independent technical authority.

Question 2. Can you update the Committee on the status of the development of the European Automated Transfer Vehicle and the Japanese H–II Transfer vehicle?

Answer. The Automated Transfer Vehicle (ATV) is at the European Space Agency (ESA) facility near Amsterdam for approximately 8 months of final assembly and verification. ESA has recently slipped the target launch date for ATV from July 2005 to October 2005 due to schedule challenges for the Ariane 5 rocket modifications that are required in order to carry the ATV.

The H–II Transfer Vehicle (HTV) development is on track for launch in Spring 2009. HTV Critical Design Review Number 1 is scheduled for December 2004. In parallel, the Japanese Aerospace Exploration Agency (JAXA) is evaluating enhanced HTV capabilities to launch and return International Space Station critical cargo and spares due to Shuttle retirement.

Question 3. Does NASA have any contingency plans in the event the Space Shuttle is not able to provide the necessary assembly flights to the ISS?

Answer. NASA is concentrating its focus on a safe Return to Flight of the Space Shuttle. All indications, as of this writing, are that the Shuttle will Return to Flight in March of 2005, after which, we fully anticipate it being able to complete its mission of the assembly of the ISS.

NASA is working diligently to evaluate the current manifest of flights to the ISS. The ISS on-orbit configuration and assembly sequence are being evaluated. The complement of available and proposed domestic and international vehicles that are capable of delivering crew, spares, experiments, and crew support cargo to and from the ISS is also under evaluation. These evaluations are expected to be complete in the summer and will provide a better idea of how many Shuttle flights will actually be needed to complete assembly of the ISS.

Question 4. Can you elaborate on how and why the ISS elements have been designed to take advantage of the Shuttle's unique volume and performance, and more benign launch environment?

Answer. The design and development of Space Station Freedom and then the ISS took maximum advantage of the large cargo volume and heavy lift of the Shuttle, which has the greatest lift capability of any U.S. Launch Vehicle. The Space Shuttle, with the greatest cargo capacity, allowed for fewer assembly flights, less complex assembly, requiring less integration, and therefore lowering the assembly risk. The additional benefit of supporting both EVA and robotic assembly of the ISS were, and still are, unique to the Space Shuttle.

Numerous ELV studies have been done over the life of the ISS Program. There is currently no other U.S. vehicle capable of automated rendezvous and proximity operations or the ability to support EVA construction or robotic assembly.

Question 5. Why does NASA predict a four to five-year delay if Expendable Launch Vehicles (ELVs) are used to construct ISS, instead of a Space Shuttle?

Answer. Current configurations of expendable launch vehicles would require extensive modification and development of a new transfer vehicle stage to transfer hardware from orbit to the ISS. Industry has told NASA they would require three to five years to develop a transfer vehicle to enable ISS cargo (non-assembly) transfer and redesign existing ISS structures and facilities to meet the ELV flight environment. Additional time would also be needed to design an ELV carrier that replicates the Space Shuttle attach points. The finished components waiting for launch were designed to fit inside the Shuttle payload bay. Currently, no domestic or partner launch systems have the capability to meet the components' volume and/or performance requirements without significant modification. A new assembly process would also need to be developed that utilizes the two-person ISS crew without the benefit of the Space Shuttle remote manipulator arm or the Shuttle crew to safely complete each assembly mission and perform required spacewalks.

Question 6. What is the cost impact of delaying the assembly of the ISS by four to five years and using Expendable Launch Vehicles (ELVs) for assembly?

Answer. The ISS program baseline, established in FY 1994, assumed the exclusive use of the Space Shuttle for all U.S. assembly missions and Partner labs after the deployment of the Russian Service Module. The Space Shuttle is currently the only vehicle capable of supporting Station assembly. The ISS was designed to use the Shuttle's automated rendezvous and proximity operations, robotic arm, and astronauts for assembly. No other vehicle can provide these capabilities at this time. The major ISS assembly elements are positioned at Kennedy Space Center awaiting Space Shuttle Return to Flight.

Industry studies indicated that non-recurring development costs for new ELV capabilities would cost a total of $700 million–$1 billion. In addition, there would be the cost of ELVs at a rate of 7–14 flights per year (the equivalent of 5 Shuttle missions per year). Finally, there would be costs associated with the ISS Program to redesign and recertify the existing modules and trusses for the EELV flight environments and loads, which would be substantial. NASA has not developed cost estimates for any Station assembly alternative.

Question 7. If the Space Shuttle returns to flight next year, what is the cost of the two-year delay in assembling the ISS?

Answer. During FY 2003, NASA funded $21 million worth of ISS impacts associated with *Columbia* and has approved an additional $76 million in FY 2004. An additional $225 million of Level I and Level II threats remain, of which $40 million is associated with the one-year slip into 2005. NASA is currently assessing the impact of the Shuttle Return to Flight schedule as a part of the FY 2006 budget development process and will update the impacts associated with *Columbia* once Shuttle Return to Flight is achieved.

Question 8. What are the attributes of an effective national space launch system and its accompanying infrastructure?

Answer. An effective national space launch system provides sufficiently capable, safe, reliable and cost-effective launch services to meet national needs. Such a system could be comprised of multiple different launch vehicles using unique or shared infrastructure.

Question 9. Considering the current restrictive budgetary environment, how can a viable national space launch system be built and how will the private sector participate?

Answer. The nation currently has a mix of reusable and expendable launch systems forming the basis of the Nation's space launch capability. Both national security and civil space launch requirements are met by commercial launch capability. NASA and the national security community work together to leverage each other's capability and seek synergy in investments in national launch capabilities

Question 10. The President's plan would terminate the Space Launch Initiative (SLI) program that was, inter alia, developing new launch vehicle technologies, and would retire the Shuttle fleet after ISS construction is completed in 2010. What launch vehicle will supplant the Space Shuttle after its retirement?

Answer. The Space Shuttle program has provided NASA with a tremendous space flight experience base. It has expanded our knowledge of complex space vehicles. The Exploration Systems Enterprise will apply lessons learned from the Space Shuttle program and SLI projects as we develop capabilities necessary to carry out safe, sustained and affordable human exploration missions to the Moon, Mars and beyond.

Over the remainder of the decade, the Space Shuttle will be used to complete assembly of the International Space Station (ISS). NASA is developing a Shuttle retirement strategy that will assure space access for required U.S. support to the International Space Station and future Space Exploration requirements. The complement of available and proposed domestic and international vehicles that are capable of delivering crew, spares, experiments, and crew support cargo to and from the ISS is under evaluation. These evaluations are expected to be complete in the summer 2004. In addition, the Crew Exploration Vehicle (CEV), which is being developed for a crewed mission to the Moon in the latter part of the next decade, could potentially be adaptable for missions to the ISS, though current development activities are focusing only on a Lunar mission.

As the Space Shuttle is phased out, and a completed ISS becomes fully operational, NASA will transition development activities to human Lunar missions on the CEV in support of the Vision for Space Exploration. To best accomplish the goals of the Vision for Space Exploration, NASA will separate its acquisition strategy for Moon/Mars exploration into a number of smaller and sequential acquisition programs called spirals. Design and demonstration of a human launch system will be demonstrated in Spiral 1 with the crewed flight of the CEV in 2014. In support of this, NASA has initiated an integrated launch system study to identify the range of launch vehicle capabilities required to meet its exploration needs, as they are currently understood. Current expendable vehicles, vehicles derived from current system components and new vehicle designs are being considered to meet exploration human launch and cargo launch needs. The study will narrow the range of possible alternatives by the end of the summer. A more focused look at the capabilities will then begin, based on a greater understanding of the CEV requirements. The study will be finalized before the CEV request for proposals are released.

Question 11. How do we encourage, to the maximum extent feasible, the development and growth of U.S. private sector space transportation capabilities that can compete internationally?

Answer. Federal agencies support the health of commercial space transportation through a myriad of roles. Most importantly, the Federal Government enables a stable business base by purchasing launch services that can leverage international and commercial sales, and through balanced regulatory and national range policies and procedures. NASA and the DOD also invest in enhancements to launch systems to meet unique government requirements (additional performance, reliability and or volume (fairings) upgrades), which increase the competitiveness of the U.S. suppliers. With recent reductions in commercial demand and a shift back to the government as dominant user of launch systems, Federal agencies are developing investment strategies that include funding key skills and infrastructure to assure that access to space is achievable.

Question 12. What role will existing Space Shuttle contractors play in the new space launch vehicle system?

Answer. NASA is beginning to evaluate future workforce needs in support of the long-term goals of human planetary exploration. The retirement of the Space Shuttle is not the end of the space program but rather the beginning of an opportunity to transition a highly skilled workforce into programs requiring their skills and challenging their creativity. We believe, at the appropriate time, these workers who have Shuttle experience will be able to continue work with NASA on new programs requiring their unique skills. As the Shuttle Program nears retirement, we fully anticipate that aerospace technician employment opportunities will continue with NASA, driven in part by the Vision for Space Exploration and the continuing need to support the International Space Station.

Question 13. Has NASA done any studies on the use of robots, such as the Robonaut, to assemble the ISS?

Answer. The current ISS Baseline is to use the Canadian Space Agency (CSA)/Mobile Servicing System (MSS) for robotic assembly and maintenance tasks. This currently includes the CSA/Space Station Remote Manipulator (SSRMS), CSA/Mobile Base System (MBS), and the NASA/Mobile Transporter to provide robotic capability to ISS using the NASA/Robotic Workstation. It will include robotic maintenance tasks to be completed via the CSA/Special Purpose Dexterous Manipulator (SPDM) after its launch currently scheduled for May 2007 on Flight 1 J/A. Many of the ISS orbital replacement units were designed to be compatible with the SPDM. The ISS has been successful with robotic assembly tasks and plans to make extensive use of robotics.

The Robonaut has worked extensively with EVA tools to perform simulated ISS assembly tasks, as both an independent agent and working with an astronaut in a pressurized suit. While not currently part of the ISS Program, the Robonaut's demonstrated capabilities indicate that it may have future ISS application. However, the Robonaut is at least 3–4 years from being certified for flight.

Question 14. It is estimated that it will require 23 to 30 Space Shuttle flights to complete the ISS. How can the ISS be completed by 2010 without causing some of the schedule pressure that was documented in the Columbia Accident Investigation Board report?

Answer. It should be noted that the requirement is to complete ISS assembly, including the U.S. components that support U.S. space exploration goals, planned for the end of this decade. NASA is evaluating the current manifest for flights to the ISS in light of the Vision for Space Exploration. The ISS assembly sequence and final configuration are being examined, as are the complement of currently available and proposed domestic and international vehicles that are capable of delivering crew and cargo to and from the ISS, and the predicted Shuttle return to flight date. This evaluation, which will factor in the historic turn around time between Shuttle flights, is expected to be complete in the summer 2004 and will provide a better idea of how many Shuttle flights will be needed to complete assembly of the ISS. NASA is evaluating ISS requirements against launch capabilities to ensure that the Shuttle can be operated safely and the ISS assembly can be completed by the end of the decade, consistent with the Vision for Space Exploration.

Question 15. What are the requirements for downmass (astronauts, experiments, equipment, ISS Components, etc.) from the ISS during both its construction and operation?

Answer. Currently, NASA is returning astronaut crews to Earth every six months. The ISS Program is currently re-evaluating the original systems maintenance approach, which would have required the periodic return of orbital replacement units for repair and refurbishment. The utilization community, in conjunction with the ISS Program, is also currently refining its estimates and looking at ways to minimize downmass. Results of these studies are expected later this year.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. TED STEVENS TO WILLIAM F. READDY

Question. Mr. Readdy, I want to commend you for the initiative the Office of Space Flight is taking to encourage development of commercial launch systems to service the International Space Station (ISS). In light of the current and future limitation on the use of the Space Shuttle, it seems to me that it is very important for NASA to pursue the development of the capacity to resupply and return equipment from the Space Station.

I understand that NASA is evaluating commercial approaches to the resupply of the International Space Station. What is your opinion of private companies' ability to accomplish this mission?

Answer. I believe commercial launch systems have a substantial role to play in future ISS resupply. Logistics is one of the most important functions of Station operation. We are working with industry to identify capabilities that might be developed to support ISS cargo requirements. We intend to complete an assessment of up and down mass requirements so that we can better understand how commercial launch services might augment our resupply capability. Later this year, NASA will release a Request for Information (RFI), to be followed by a Request for Proposals (RFP) in 2005, to acquire capability as soon as practical and affordable to support cargo missions to and from the ISS and for meeting ISS operations requirements after ISS assembly is complete and the Space Shuttle is phased out of service.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN MCCAIN TO RADM CRAIG STEIDLE (RET.)

Question 1. Mr. Readdy's written statement states that the International Space Station (ISS) is preparing us for future human exploration in many ways, and that it is an exploration research and technology test bed. How critical is the completion of the ISS to the success for the President's Space New Vision? Is it on the critical path?

Answer. In support of the Vision for Space Exploration, NASA will pursue international participation. Hence, it is important that NASA fulfill its commitments to our international partners—including flying the partner modules to the ISS. Furthermore, U.S. research on board the ISS will be refocused to better understand and counter the effects of space flight on astronaut health. Just as Gemini programs produced the knowledge that allowed us to reach our Apollo-era objectives, what we learn from ISS missions today and in the next few years will help us achieve the goals of traveling to the Moon, Mars, and beyond. ISS is on the critical path as a testbed for demonstration of future technologies as well as future operations and engineering capabilities.

Question 2. Can you discuss your plans to include government diligence in the area of system engineering when programs and their contractors are in periods of transition and/or under severe cost pressures?

Answer. A strong systems engineering and integration capability will provide the foundation for implementing the Spiral Development process. The government will work in partnership with industry to implement a strong systems engineering structure, relying on lessons learned from NASA and DOD programs. NASA has asked the National Academy of Engineering to recommend criteria for developing the systems engineering capability that will be required to integrate this complex system of systems and to execute a sustainable and affordable space exploration program. Critical elements of the systems engineering function will be a robust risk management process and independent cost assessment. Requirements development based on sound systems analysis is currently under way. These requirements will be validated by system concept designs by government and industry teams through directed government tasks and industry contracts from the Concept Exploration and Refinement Broad Agency Announcement that was released on June 14, 2004.

Question 3. Can you explain the spiral development concept?

Answer. Spiral Development is an overarching strategic principle that the Exploration Systems Enterprise has adopted for the development of new capabilities. A single step acquisition strategy for a human presence on the Moon, as a precursor to Mars exploration, involves many uncertainties. To manage those uncertainties, the Enterprise is developing new capabilities in stages or "spirals" with evolving modular components. All spirals will be structured based on a well-defined end state, specific requirements, current technologies, manageable risks, an executable budget, and knowledge gained through lessons learned from prior missions. To lower cost and improve performance, the Enterprise invests in the maturation of technologies for incorporation within modular components and inclusion in future spirals when the technologies are mature. In this way, technology development will transform future spirals without placing program execution at risk.

In the first spiral, the focus will be on low-earth orbit operations. High-level milestones are: the flight of a prototype in 2008; uncrewed Crew Exploration Vehicle (CEV) in 2011; and a first crewed CEV flight in 2014. In the second spiral, we will develop capabilities for extended human and robotic exploration on the moon. Future spirals will evolve based on the successful deployment of new capabilities, technology maturation, scientific discoveries, and budget and policy priorities.

Question 4. There has been some discussion of canceling the Space Shuttle, and using funding from that program to accelerate the implementation of the President's New Space Vision? How would canceling the Space Shuttle affect your plans for development of the Crew Exploration Vehicle?

Answer. The Vision for Space Exploration directs NASA to return the Space Shuttle to flight, focus use of the Space Shuttle to complete assembly of the ISS, and retire the Shuttle as soon as assembly of the ISS is completed, planned for the end of the decade. If the Space Shuttle were retired earlier than 2010, development of the CEV could likely be accelerated. The accelerated development may be possible because NASA could redirect funds now required to operate the Shuttle to support CEV development and other exploration activities. However, retiring the Space Shuttle before ISS assembly is complete would significantly impact the Nation's ability to conduct human space exploration and might prevent the United States from meeting its obligations to the international partners. Early Shuttle retirement could only be achieved by significantly reducing the final configuration of the ISS, which might prevent completion of vital ISS research that is needed to enable humans to travel back to the Moon and then on to Mars.

Response to Written Questions Submitted by Dr. George E. Mueller, Chief Executive Officer, on Behalf of Kistler Aerospace Corporation

On May 5, 2004, the Senate Subcommittee on Science, Technology, and Space held a hearing regarding "Space Shuttle and the Future of Space Launch Vehicles." A number of questions were raised by Mr. Elon Musk of Space Exploration Technologies (SpaceX) in the oral and written testimony regarding Kistler Aerospace Corporation, the K–1 reusable aerospace vehicle, and Kistler's contract with NASA. In particular, Mr. Musk raised questions about the General Accounting Office (GAO) review currently underway regarding this NASA contract.

It is our strong view that many of these points were either misleading or inaccurate, and we respectfully submit the following statement in order to clarify our position. Thank you for the opportunity. Kistler Aerospace Corporation would be happy to respond to future questions and would make itself available to the Subcommittee in any relevant context.

Question 1. Who is Kistler Aerospace Corporation and what is the K–1 reusable aerospace vehicle?

Answer. Kistler Aerospace Corporation is a privately funded, U.S. small business, headquartered in Washington State. Kistler is developing the K–1 fully reusable aerospace vehicle, designed to deliver payloads to orbit and provide a low-cost alternative to single-use launch vehicles. The company intends the K–1 to become the reliable, low-cost provider of launch services for commercial, civil, and military payloads destined for a wide range of orbits. The K–1 mission capability includes cargo resupply to and return from the International Space Station (ISS); satellites, scientific payloads and technology experiments to Low Earth Orbit (LEO), Medium Earth Orbit (MEO), Geosynchronous Transfer Orbit (GTO); and space exploration missions to the Moon, Mars and Beyond.

Kistler's senior management team has been involved in the United States space program for decades. I was the first head of the Office of Manned Space Flight at NASA, directed the program that put the first American on the moon, conceived the Shuttle and Skylab programs, and authored 'An Integrated Space Plan,' which has guided our space programs since 1970.

When I joined Kistler in 1995, several of my former associates assisted me in developing the requirements and architecture of the K–1 vehicle, including Dale Myers, former President of North American Aircraft Operations and Vice President of Rockwell International (in charge of the B–1 bomber program) and former NASA Deputy Administrator and Associate Administrator of Manned Space Flight; Aaron Cohen, former head of NASA Johnson Space Center (JSC); and Henry Pohl, former Chief Engineer for JSC and ISS. Today, Joe Cuzzupoli, former Rockwell program manager for the Space Shuttle Orbiter project, and Dick Kohrs, former program director of NASA's Space Station Freedom and deputy director of the Shuttle, are in charge of completing the design and overseeing the manufacturing of the K–1.

One of my legacies from the Apollo program was the use of "all-up" testing on the Saturn V launch vehicle. This means that we designed, built, and tested the same full-scale Saturn V that was used to put men on the moon. We are using a similar process with the K–1. The K–1 in development today is the vehicle that will fly initial missions, starting with the very first flight.

Kistler is the owner/operator of the K–1 program, with detailed design, manufacturing and test done by our contractors. Our contractor team includes some of the best the United States has to offer: Northrop Grumman Corporation (composite structures); Lockheed Martin Space Systems—Michoud Operations (aluminum propellant and oxidizer tanks); Aerojet—General Corporation (propulsion systems); Honeywell (avionics); Draper Laboratory (guidance and control); Irvin Aerospace (landing systems); Oceaneering Space Systems (thermal protection); as well as a number of smaller contractors.

At the height of the K–1 development program, over 1,200 jobs were located in more than seven states, including Washington, California, Louisiana, Texas, New Jersey, Massachusetts and Florida, with additional testing conducted in Arizona and Virginia. This represents hundreds of millions of dollars of private investment. For plans going forward, these same contractor teams will be employed on the K–1 program, also funded by private investment.

As a result of the efforts of our management, employees and contractor team, our first K–1 vehicle is 75 percent built, 85 percent design complete, and first guidance, navigation and control (GN&C) flight software is 100 percent complete. All system requirements tasks have been completed, and numerous tests conducted, including full-length firing of the K–1's main rocket engines, full-scale drop tests of the parachute recovery system, and Hardware-in-the-Loop testing of the K–1 flight avionics hardware and software.

The K–1 will provide affordable, responsive access to space for many customers—NASA, Department of Defense and commercial—using the same vehicle and leveraging the inherent reusability and on-orbit maneuvering capability of the K–1. The K–1 can deliver 12,500 lbs to LEO (due east) as well as 3,500 lbs to GTO and 2,000–3,000 lbs to interplanetary targets (with an Active Dispenser upper stage). For future ISS resupply flights, our K–1 vehicle can deliver 7,000 pounds of pressurized cargo to the ISS, return more than 2,000 pounds of recoverable down mass to earth, and have the capability to reboost the ISS up to 40 miles. As a result we are the most likely new candidate for America to maintain vital support of an asset, the ISS, that the U.S. has spent significant dollars to create and within which we trust the lives of our astronauts. The K–1 will have the capability to service the ISS as frequently as needed, with regular monthly flights for routine logistics and launch on demand service.

*Question 2.*What is the contract that Kistler Aerospace Corporation has with the National Aeronautics and Space Administration (NASA)?

Answer. NASA awarded our current contract to Kistler in May 2001 as part of an open competition known as the Space Launch Initiative. On the same day, NASA awarded a total of 22 contracts worth over $800 million to industry and university organizations. Under our existing contract, NASA is entitled to obtain and use pre and post flight data from 13 "embedded technologies," which are technological innovations already built into the K–1 that are useful for future aerospace systems. In addition, NASA can exercise options to obtain data from one K–1 flight demonstrating its capability for Autonomous Rendezvous and Proximity Operations (ARPO). This data will demonstrate the ability of the K–1 and vehicles like it to navigate to and berth with the ISS, as well as have synergy with other commercial and military applications for on-orbit maneuvering.

In February 2004, NASA issued a synopsis announcing its intent to exercise existing options and modify our existing contract to add data from four additional ARPO flights—flights in which the K–1 will demonstrate that it can navigate progressively closer to the ISS. NASA's decision came only after an extended process in which NASA evaluated the alternatives and concluded that only Kistler is in a position to meet NASA's needs in the time frame required. NASA recently issued what is known as a "JOFOC", or justification for other than full and open competition, describing this process. There is no doubt that NASA's decision is good news for Kistler. The original contract value, as announced by NASA, was worth up to $135 million, and the modification brings the total contract to approximately $227 million (of which $8 million has already been paid for data deliverables).

Kistler's contract with NASA is a good deal for the government. NASA pays neither to develop the K–1 vehicle nor for launch services. *Rather, NASA pays only for data, and only upon performance.* It has no obligation to pay until data are delivered and accepted. This allows the government to leverage private capital investment in the K–1 for broad government and industry benefit, without any upfront risk or expenditure. Further, NASA has made clear that any contracts for ISS resupply launch services will be subject to a separate procurement. Kistler has supported this position completely.

One of our competitors, a company called Space Exploration Technologies (SpaceX), has protested NASA's decision with the General Accounting Office (GAO). Kistler believes that NASA acted properly, and indeed did more than was required to evaluate the alternatives. In the end, the GAO will decide the protest (expected by July 9, 2004), and we have every confidence that the outcome will sustain NASA's award to Kistler.

SpaceX has also recently sought to make Kistler's contract with NASA a political issue, presenting a blurred view of the facts, and even seeking to introduce testimony regarding the contract at the above-referenced Hearing of this Senate Subcommittee on another matter, which the committee declined to hear. We regret SpaceX's approach, if for no other reason than it seeks to circumvent the GAO's process and unnecessarily delays data that America's space program really needs, and that Kistler is in the unique position to provide.

Question 3. What is Kistler's financial situation?

Answer. Kistler is a privately-funded, U.S. small business, and has raised more than $600 million in private investment and spent more than $800 million on the K–1 program. This is a significant undertaking, particularly in an industry where nearly every existing launch vehicle has been funded by government development money.

In order to restructure our existing debt and equity and to enable us to raise additional capital to complete the development of the K–1 Program, Kistler filed for relief under Chapter 11 of the U.S. Bankruptcy Code on July 15, 2003. Continuing business as usual, we have operated post-filing as a debtor in possession (DIP) and arranged for in excess of $4.5 million of financing from our primary pre-filing secured lenders.

Bay Harbour Management LLC, a well-known firm specializing in reorganizing and funding distressed companies, has committed to lead the financial reorganization of Kistler. We anticipate filing a plan of reorganization that will restructure the current debt and equity and enable us to secure approximately $450 million of new capital that sets the stage for completion of the K–1 program.

We fully expect to emerge from Chapter 11 this year, with the first K–1 flight expected to occur 15–18 months after re-start.

Although Kistler continues to function and is fully confident it will reorganize stronger than ever, it is important to reiterate that even if we were to fail, the government still has no liability whatsoever. The contract is a "pay-for-performance" contract with a set expiration date. Only when we have produced does the government pay. If we cannot produce the data, the government does not pay.

Question 4. What engines are used by the K–1 reusable aerospace vehicle?

Answer. Liquid-propellant engines from Aerojet, a leading U.S. propulsion contractor based in Sacramento, California, have been selected to power the K–1. The two AJ26–58 and one AJ26–59 engine on the first stage and the AJ26–60 engine on the second stage are U.S. modifications of the fully developed, extensively tested core of the NK–33/NK–43 engines originally designed for the Russian Manned Moon Program in the mid 1960s and subsequently placed in storage in Samara, Russia, for over two decades.

Aerojet purchased a large quantity of these engines in the mid 1990s, and currently has 47 at its Sacramento facility—enough for up to 180 flights of the K–l vehicle. Aerojet also has in its possession the intellectual property (engineering drawings, materiel specifications, etc.) and the licensing provisos for U.S. modifications and/or production, contingent on a case-by-case approval of the end-use of these engines. Approvals were obtained for use of these engines on the Kistler K–1 vehicle.

To meet the K–1 requirements, Aerojet has already modified, upgraded, and test-fired a number of the engines with modern U.S. electronic controllers, ignition systems, control valves, and thrust vector control systems.

Question 5. What launch sites is Kistler planning?

Answer. Kistler Aerospace Corporation currently plans to establish two launch sites for operating the K–1 reusable aerospace vehicles: Woomera, Australia and Nevada, USA. Environmental approval has been received at both sites. Test flights and initial commercial operations are planned from Spaceport Woomera, located in the Woomera Prohibited Area, a 127,000 square kilometer region in the desert of South Australia, about 470 km (280 miles) north of Adelaide. A second launch site is planned in the U.S., at the Nevada Test Site, near Las Vegas, Nevada, USA, after demonstrating successful flights in Australia. The launch sites will have nearly identical facilities, infrastructure and support equipment. Reynold Smith and Hill (RS&H) of Merritt Island, Florida, which designed launch pads at Cape Canaveral, has completed detailed design of the K–1 launch facility and support equipment.

Woomera, Australia, has over a 50-year history supporting space programs, including a long and strong relationship with the United States. For example, the U.S. Redstone rocket successfully deployed the WRESAT satellite in 1967; NASA Black Brandt sounding rockets have been launched from there; and from 1968 through 1999, Woomera supported joint U.S./Australian defense operations at Nurrungar (about 19km south of Woomera Village) for the then-classified Defense Satellite Communication Station, used as an intelligence outpost for early warning. Woomera is an ideal base to safely conduct orbital launch and recovery operations for reusable vehicles in terms of existing infrastructure, population density, topography and weather.

The process of obtaining a license from the FAA, for launch and recovery on land, represents a major hurdle for any fully reusable aerospace vehicle. As an alternative, Kistler selected Woomera with the full understanding of the Federal Aviation Administration's Commercial Space Transportation Organization (FAA/AST). Kistler plans to re-engage with the FAA/AST after successful K–1 flights in Australia using actual flight data to obtain the license. Nonetheless, the option of flying first commercially in the United States is not available as long as the FAA/AST assumes a probability of failure of one during overflight.

In addition, Kistler has surveyed multiple other sites for suitability of potential K–1 operations in the continental United States, including the Fort Stockton area in Texas, the X–33 facilities in Edwards, California, the Alamagordo area in New Mexico, as well as the Florida Space Authority regarding potential launch and landing sites at Cape Canaveral. Undoubtedly, having a U.S. site—earlier rather than later—would facilitate easier logistics for some potential K–1 customers.

In closing, thank you for the opportunity to submit this response for the record. Please feel free to contact me with any questions. Additional information on Kistler Aerospace Corporation and the K–1 reusable vehicle can be found on our website at: *www.kistleraerospace.com* or by E-mail request to *info@kistleraero.com.*

RESUMÉ OF DR. GEORGE E. MUELLER, CHIEF EXECUTIVE OFFICER

Dr. George E. Mueller is Chief Executive Officer of Kistler Aerospace Corporation, developer of the K–1 fully reusable aerospace vehicle. He joined Kistler, a privately funded small business, in 1995, continuing a distinguished career in space, science, engineering and corporate management. Dr. Mueller led the program that put Americans on the moon. In 1963, having led successful space programs at Ramo Wooldridge Corporation, he was selected to take over the Apollo Project by NASA Administrator James E. Webb. As Head of Manned Space Flight, he was responsible for the Gemini, Apollo and Saturn programs, while the Kennedy, Marshall and Johnson Space Centers reported to him. From the beginning of Gemini in 1963 through the second Apollo moon landing in 1969, Dr. Mueller directed the U.S. Space Program as NASA Associate Administrator for Manned Space Flight.

Mueller's leadership made possible the achievement of the national goal set in 1961*: the landing of men on the moon and their safe return to Earth by the end of the decade.* To accomplish this goal, he synergized the activities of 20,000 industrial firms, 200 universities and colleges, and hundreds of thousands of individuals into one concerted effort. Throughout the highs and lows of the Apollo program, George Mueller inspired industry, NASA, the citizenry, and the legislative and executive branches of the government to overcome adversity and meet the challenge of the Apollo program.

George Mueller is also the originator of Skylab, the world's first space station, and is regarded as the "Father of the Space Shuttle." His post-Apollo plan, "An Integrated Program of Space Utilization and Exploration," became the guiding document for NASA for the past several decades.

After leaving NASA, Dr. Mueller was Senior Vice President of General Dynamics Corporation, Chairman and President of System Development Corporation and Senior Vice President of Burroughs Corporation.

George Mueller began his career in 1940 as a Member of the Technical Staff with Bell Telephone Laboratories where he designed the 10cm "polyrod" antenna and other receivers. From 1946–1957 he was a Professor of Electrical Engineering at The Ohio State University where he developed the communications engineering curriculum and laboratories.

Dr. Mueller is a Member or Fellow of the American Association for the Advancement of Science, National Academy of Engineering, American Geophysical Union, American Astronautical Society, Institute of Electrical and Electronics Engineers, Royal Aeronautical Society, and French Academy of Astronautics. He is an Honorary Fellow of the American Institute of Aeronautics and Astronautics (AIAA) and British Interplanetary Society. Dr. Mueller has served as President of the AIAA from 1979–1980 and of the International Academy of Astronautics from 1982–1997.

Dr. Mueller holds a Ph.D. in Physics from The Ohio State University, an M.S.E.E. from Purdue University, and a B.S.E.E. from the University of Missouri at Rolla. In addition, he has honorary doctorates from six universities. Eighteen international awards have been bestowed on him, including three NASA Distinguished Service Medals, Apollo Achievement Award, American Astronautical Society Space Flight Award, American Academy of Achievement Gold Plate Award, Elmer Sperry National Transportation Award, Medal of Paris, American Institute of Aeronautics & Astronautics Goddard Medal, International Peace Cooperation Award—Russia, Gagarin Space Medal, United Societies in Space 1997 Space Humanitarian Award, the National Space Society's Wernher Von Braun Memorial Award, the National Award for Space Achievement in 2002, one of Aviation Week's Top 100 Stars of Aerospace, and the American Astronautical Society's Lloyd V. Berkner Award. Dr. Mueller was awarded the National Medal of Science for his many individual contributions to the design of the Apollo systems.

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