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ASSESSING COMMERCIAL SPACE CAPABILITIES

HEARING

BEFORE THE

SUBCOMMITTEE ON SCIENCE AND SPACE

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

ONE HUNDRED ELEVENTH CONGRESS

SECOND SESSION

MARCH 18, 2010

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ASSESSING COMMERCIAL SPACE CAPABILITIES

THURSDAY, MARCH 18, 2010

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

The Subcommittee met, pursuant to notice, at 2:48 p.m. in room SR–253, Russell Senate Office Building, Hon. Bill Nelson, Chairman of the Subcommittee, presiding.

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

Senator NELSON. Good afternoon. The hearing will come to order.

It should be quite obvious to us by now that the NASA budget, rolled out on February 1, in the President's request, was, to use some NASA words—in an "off-nominal fashion." I can tell you for a fact that the perception is that the President has gutted the human spaceflight program. But, that, in fact, is a perception, not a fact.

I know the President, and I know him to be a true believer when it comes to this Nation's spaceflight program, especially the manned program, and that is the reason the President has, in part, decided that he is coming to the Kennedy Space Center on April 15. And we will hear from the Commander in Chief himself when he hosts that meeting to discuss his new plan for NASA and for the future of human spaceflight.

I think the Administration will focus on the goals, the strategies, timelines of their plan, and I think that the President will lay out an underscored commitment to the development of technology to pursue a goal that was articulated by the NASA Administrator here in this hearing room a couple of weeks ago.

I think this conference is going to be an important step in response to the concerns that have been expressed by the American public, as well as by their representatives in Congress. And I expect the President to lay out his vision and what the goals and the timelines are for America's manned space program.

Now, the question is, what are going to be the elements of bringing about a major R&D effort for, ultimately, a heavy-lift vehicle to get us out of low-Earth orbit? As the President has laid out—the good news of his budget has been lost in a lot of the misperception—NASA is a little civilian agency and he is recommending a $6-billion increase for NASA over 5 years. That's a fairly sizable increase, given these financial times, in which one of the

main things that the U.S. Government has to do is tackle the budget deficit and start driving it down to get us back into balance.

The other major piece of good news that has been overshadowed—and I never cease to be amazed, as I talk to people—that, in what I have just talked about—the perceptions—this news has been completely lost. And that is, in the budgeting, up until now, the International Space Station was going to cease to exist in 2015, which, of course, was absolutely ridiculous, from a budgetary planning standpoint, because we haven't even got it completed yet. And it's just about to be completed and equipped so that, with its designation as a National Laboratory, it can start to achieve some of the science, through experimentation in the zero-G environment, that we've all hoped for; and therefore, in the President's budget, he adds extra expenditures to keep the Space Station going until at least 2020.

It is my hope that the President will also recognize the angst that is out there in the NASA family, because not only are we in a recession where various parts that have a major part of the employment of the Nation's Space Program are severely hurt, because of high unemployment figures, which is certainly the case in Florida, but the angst is out there because all of this dedicated team, that is the finest launch team in the world, is facing layoffs. And all of this is coming during a difficult economic time in an economic recession. And this is coming not as a result of these budget decisions, but budget decisions and safety decisions that were made years ago. And therefore, because these budget decisions were made over the last half-dozen years, the new rocket is not ready when the Space Shuttle is going to be shut down, and as a result, there is a gap without an American vehicle to launch crews to the International Space Station. And that has caused a great deal of angst, as it should, because, if you're laid off of your job, it's not a recession, it's a depression.

Because the word, in the President's budget, was used, "cancellation," instead of the word "restructuring" of Constellation, it has caused a good bit of angst, understandably so.

Now, what to do about it? Well, the President's policy that he's proposing to us, which is the subject matter of this hearing, is that the trips to and from the Space Station, for both cargo and crews, can be done cheaper and more quickly by letting the commercial sector compete in the free market, with NASA oversight on the human rating, to get crews up and back from the Space Station. And I know it to be the President's intent that, simultaneously, he wants the vigorous R&D work in the development of the new systems to take us beyond low-Earth orbit. And I think, in large part, that's what he will be addressing when he comes to the Space Center.

There's one other little iteration that I would certainly encourage him to consider, and that is that there is a fifth Shuttle that can fly. It is held as the launch-on-demand, as a rescue Shuttle if any of the remaining four get into trouble. But, the risk for the fifth flight would be de minimis because of the increased volume in the Space Station that, should some kind of puncture of the orbiter occur on ascent in the fifth flight, they could rendezvous and dock, take safe harbor in the International Space Station, and then there

would be time, through the *Soyuz* modules, to return that crew safely to Earth, if the worst did happen. But, of course, NASA has so improved—since the destruction of *Columbia,* so improved its ability to make those flights safe. And so, I would argue to the President to have a fifth Shuttle flight.

If you ask about additional flights, well, the hard reality sets in. It has been planned for—the shutdown of the Space Shuttle—for some period of time. And therefore, the external tanks which would drive future Shuttle flights are not assembled and are in disparate parts. And when I asked this question of Bill Gerstenmaier, "You have parts out there for three additional tanks. How long would it take you to get that?" and he says, "By the time you recall the workforce and you get the parts where they can be assembled and you can do all the checks and you can get additional parts that you need that you don't have," he said, "it is 2 to 2½ years down the road before you could fly." And as a practical matter, that doesn't solve our problem, to wait around another 2, 2½ years, when, in fact, the Space Shuttle is scheduled to be shut down after the fourth flight. I'm hoping the fifth flight will fly.

And so, we turn to you all. We turn to the commercial people, and that's what we want to explore here today.

COTS is being executed in two phases, the first period of private industry development and demonstration of the various space transportation capabilities to and from Earth orbit. This phase, which has already seen a significant investment on the part of NASA, will be funded, according to the President's request, at $312 million in the Fiscal Year 2011 budget to expedite the pace of the development. And the second phase is competitive procurement of orbital transportation services to supply the ISS. And this phase will be funded through the Space Operations Mission Directorate, under the ISS Cargo Crew Services Line, beginning in earnest in Fiscal Year 2011.

Now, on commercial crew to the ISS, the effort was initiated using the 2009 Recovery Act funds. That's otherwise known as the "stimulus bill." And that enables future commercial crew launches to the ISS. Space Act agreements were awarded to five companies in February of this year to demonstrate the various technologies and capabilities necessary to reduce the risk of flying crew on commercial vehicles, with completion milestones in November and December of this year.

And then, the follow-on commercial crew program, under the President's recommendation, is $6 billion over the next 5 years to support the development of commercial crew providers, then to whom NASA would turn to competitively award transportation service contracts that are similar to the cargo resupply services contracts. And this program is going to be open to a broad range of commercial proposals, including the human rating of existing launch vehicles, the development of spacecraft for delivering crew to the ISS, which can be launched on multiple launch vehicles, and the development of a new, high-reliability rocket system or systems.

And so, what we're going to do today with all of you experts is, we want to take a look at these plans and see how this fits into the broader goals and visions for NASA, a vision that has been

stated by the NASA Administrator, ultimately, to go to Mars. And we'll see what the President says.

Now, what we'd like to glean from you all is also better understanding of how that $6 billion for man-rating the systems is going to be spent. And we want to explore the safety and regulatory aspects of the new plan. And obviously there can be no compromises on safety. I will put into the record a statement that the Aerospace Safety Advisory Panel has stated on exactly that.

[The information referred to follows:]

"It is crucial that NASA focus on establishing the certification requirements; a certification process for orbital transportation vehicles; and a process for validating compliance. The performance and safety requirements must be stated promptly and clearly to enable NASA and non-NASA entities to proceed in the most productive and effective manner possible."

Senator NELSON. And so, it's going to be important that NASA work with the industry to complete a coordinated human-rating draft by the end of this year—by the end of this Fiscal Year, which ends September 30.

And contracting commercial services is another area of interest which is going to be critical here. How will funding be allocated to this effort during the R&D phases and then during the operation phases? And how will investments be divided between government and private sectors as the capabilities move forward? And how do we ensure these commercial entities remain viable once they have taken responsibility for these extremely important missions?

And so, we're also going to hear from some of the companies today who are competing in this effort, to better understand your capabilities and timelines and challenges.

And so, instead of introducing all of you at once, I'm just going to go right down the line, and I will introduce each one of you.

Your written record is inserted in the record and made an official part of the transcript.

What I'd like you to do is be mindful that we have seven up here. And I've already taken too much time, but I wanted to set the table. If I can hear from you all, each, about 5 minutes, and then we'll get into a lengthy set of questions. I'm in no hurry to leave this afternoon.

Our first is Lieutenant General Tom Stafford, United State Air Force, Retired, the acclaimed astronaut who flew down close to the surface of the Moon, who flew that mission that, in the midst of the Cold War, brought about a little bit of thaw, as a Russian—then Soviet—spacecraft rendezvoused and docked with an American spacecraft, and the crews lived together for 9 days. And he's going to discuss the impact on astronaut safety in transitioning the delivery of the crew from the Space Shuttle and *Soyuz* to the future commercial spacecraft.

General Stafford, thank you for coming.

STATEMENT OF THOMAS P. STAFFORD, LT. GENERAL, USAF (RET.), FORMER NASA ASTRONAUT

General STAFFORD. Thank you, Mr. Chairman.

It's an honor to be invited to appear before you today to testify on the matter of crew safety and human spaceflight.

And in the wake of the Augustine Committee report, and now the 2011 budget, the issues that you outlined, Mr. Chairman, it is imperative that this Congress should carefully consider and understand all the potential ramifications and the proposed changes to be made to the program that NASA has pursued and that the Congress has approved over the 4 years of the human spaceflight recently.

And before proceeding to answer the question, I'd like to make just a few observations concerning the Augustine Committee report, and then, particularly, my experience with the *Gemini* Program, which was taking an existing vehicle and modifying it there for human-rated standards.

And one of the most important observations of the Augustine Committee was the underlying concern and the deliberations on the future of human spaceflight has been inadequately unfunded for many years now, and you've already outlined that, Mr. Chairman, in your discussion. And it's really inadequate in certain ways, what they had previously, to carry on the core efforts.

The Augustine also pointed out that the heavy-lift launch vehicle will be required for the flexibility to visit the Moon and other areas.

Now, the plan that NASA had proposed, that has been approved by this Congress, was a program offering a strategic vision for human spaceflight that was demanded by Admiral Gehman and the Columbia Accident Board. It is a program worthy of our Nation. And the Augustine Committee noted, as you pointed out, sir, that at least $3 billion per year must be added to appropriations to accomplish that mission.

He also pointed out that Mars should be the final, ultimate destination for human exploration of the interplanetary system, but that the flexible path or to visit the Moon is also not mutually exclusive, and I agree completely there with that committee.

The choice is plain: Either we'll provide the funding necessary to accomplish the worthy objectives of our Nation or cede the leadership. And I think everyone is—understand that, and you elegantly outlined that in your effort there.

And I've talked to many of the members after my—I was the first presenter to the Augustine Commission, Mr. Chairman, and after the Committee had its findings, I've talked to the ones that I knew personally, told them that I agreed with about 90 percent of their findings, but I had a—certainly, a different point of view in about 5 to 8 percent of their findings. And I'm not familiar with all aspects of the proposed 2011 budget, or all the aspects of NASA's response to it.

And I certainly agree with—as you outlined, remaining Space Shuttle flights should be launched on schedules compatible with safe test checkout and launch operations.

And then, that fifth Shuttle we have on standby-on-need could be launched very easily, if a small amount of funding was available. And that would certainly enhance the viability of the International Space Station, Mr. Chairman.

Now, the—again, as the Augustine Commission had its findings extending—that was one of my first recommendations, was to ex-

tend it from 2015 to 2020. And that is in the budget, as I've read in a macro view.

And to have and to use this great international laboratory requires this guaranteed space transportation capability as soon as possible after the Shuttle retirement. And the—but also, the Augustine Commission had the finding that that responsibility be removed from NASA and offered to commercial providers. Yet, today approximately 83 percent of every NASA dollar goes to commercial providers directly.

And I'd like to differentiate the two subjects—and I think you've already mentioned it, Mr. Chairman—concerning the commercial crew delivery to the Station and commercial cargo delivery to the Station. And for the commercial cargo delivery, there first has to be the development and the demonstration of a safe, reliable booster to Earth orbit, which is yet to be demonstrated.

And the second issue, an autonomous transfer vehicle to go from low-Earth orbit to the Station in a safe manner that will meet the ISS visiting spacecraft standards. This was recently completed by the European Space Agency's ATV and Japan's HTV. The ATV was approximately 2 years late from its target, and required approximately 1.3 billion Euros for development and delivery of that first vehicle. The HTV was over 1 year late in their delivery.

With respect to the commercial crew launch delivery, I'd like to recall my own experience of *Gemini* since we modified existing vehicle. I've flown—I flew two *Gemini* missions on modified *Titan II* boosters, and as you know, two *Apollo* missions, one on a small *Saturn,* one on a giant *Saturn.* The period of 13 years I was at NASA, experienced the development of high reliability of boosters, spacecraft, and launch-abort systems. And then—and the pilot of *Gemini VI,* the world's first rendezvous—on that mission, the *Titan II* ignited and shut down at T=0. And we had the lift-off signals and a fire broke out down below. But, the extensive modifications that NASA and the Air Force had made to that booster made it possible that I'd be speaking before you today, Mr. Chairman, and not be in some obituary column. So, I have a significant interest in the safety.

And there were several black areas of the launch trajectory of the *Titan II*/*Gemini* program. It was basically—the *Titan*/*Gemini* program was a high-risk demonstration program which would not be acceptable today, in terms of safety.

And I think it's important for all the commercial providers here today to understand that when the NASA first, you know, put forth the idea of flying the *Gemini* on the *Titan,* the Air Force strongly resisted this. The program manager and his production line did not want modifications going into those vehicles. And it escalated all the way up to the Deputy Administrator, Dr. Robert Seamus, talking to the Secretary of the Air Force, and then finally, Administrator, Mr. Jim Webb, and Secretary of Defense, Robert McNamara, signed off on an agreement. And in that, the elements for the Titan that would go to *Gemini* would be specially—had special quality assurances in the plant in Denver, but a complete separate program line was set up in the Martin Baltimore plant. And there, the modifications were put on it—dual redundant hydraulic systems, all the series of modifications, standpipes, accumulators to

prevent POGO. And from the Aerojet company that supplied the engines' first and second stage had special handling of those for the Titan, and an escort with them all the way to install at the Martin plant, and stayed with the booster all the way to the launch at the spacecraft. So, it was very extensive, what we did. And we all spent hundreds of hours, both at the spacecraft and with the booster, in that period of time. So, it was not simple to have that whole effort there.

And it's interesting to note, that after the Air Force-NASA experience on that, the Air Force modified their boosters with a lot of our programs that we had in there.

And from there—the safe, reliable delivery of government crews to the ISS involves the human-rating of the launch vehicle, the spacecraft, and the launch-abort system. And the successful integration of all three elements has to be there. The safety goal for *Apollo,* sir, which I flew, had 0.9999—four nines. Now, I know the Astronaut Office has put out a paper that has three nines, and when you go beyond the third nine, it may be insignificant, but this is a desirable number to meet, and it has to be demonstrated. And the process begins with the design, the construction, all the way through. And that's just not given on a piece of paper, it has to be demonstrated and checked on.

Unfortunately, the Augustine Committee report gave only a brief mention of crew safety for launch operations and reentry. And regrettably, there were no indepth discussions of the vital issue of this crew safety, safety launch, and orbital return of the crews. It was just taken as safety is a given. And I've mentioned that directly to Norm, so he knows about it.

And it may be the complexity of developing a new government crew space transportation capability and the difficulty of conducting spaceflight operations and safety, reliable—is not fully appreciated by those—the present systems being developed by NASA and the early adaptation of presently nonexisting commercial government crew vehicle alternatives. There's some—seems to be some belief that if NASA would just step aside, then private alternatives would rapidly emerge to produce a safe, reliable, dependable government crew delivery space transportation.

And human spaceflight is the most technically challenging demand of our own time, Mr. Chairman. It is far more demanding than military fighter aircraft, which takes thousands of hours of test flight—the operational test and evaluation before it's put in service. And the same way with commercial airline before they're put into commercial service.

And we've learned a lot over those years, but the—we know that there has to be this demonstrated reliability. And it's interesting to note, I—the Augustine report in great detail, and it said if less constrained budgets were available, they could fly as early as 2016. But, again, looking at the present budget, it was a slight increase, but it wasn't to the increase that Mr. Augustine had in his findings.

It did go on to say, with an item I agree, "The Committee recognizes the development of commercial services to transport crew come with significant program risk." And then it goes into their, "One risk is a—can detract from the delivery of the cargo." But the

second one is, "If the commercial community fails to deliver this crew vehicle in mid-program, then it would revert back to NASA." And the big issue there, for NASA and the whole country, is, How could it revert in a meaningful way to NASA, when all their support contractors are gone, and furthermore, a lot of the civil servants have left? And it went on to say, "There are simply too many risks at the present time to have a viable fallback option of not having risk mitigation." So, the question is, How do we have risk mitigation when, as far as we know, the present program is pretty much eliminated?

And there's one minor thing, too, at the end. It said that they need to be multiple providers for this. And this would be similar, sir, like the—we have the F–22, which I'm sure that every member knows about—the most capable aircraft in the world—air-to-air combat—and the most expensive—which was recently terminated. That started as the YF–22, and the YF–23 by the Air Force. And developers chose the 22 for development tests, evaluation—operational test and evaluation in the service.

Reading the report—and I talked to the person who wrote this chapter—he said, "Yes, you need both." So, that would be like taking the F–22 and the F–23, taking them all the way. So, that would take many tens of billions. So, on that one, I disagree, Mr. Chairman.

The—so, there are many aspects to this, and there are a lot of things that has to go forward, and I do not believe it can happen in any short period of time.

Thank you.

[The prepared statement of General Stafford follows:]

PREPARED STATEMENT OF THOMAS P. STAFFORD, LT. GENERAL, USAF (RET.), FORMER NASA ASTRONAUT

Chairman Nelson, Ranking Member Vitter, and members of the Subcommittee, I am honored to be invited to appear before you today to testify on the matter of crew safety in human spaceflight. In the wake of the Augustine Committee report and now the President's 2011 Budget, it is imperative that this Congress should carefully consider and understand all of the potential ramifications of the proposed changes to be made to the programs that NASA has pursued and that the Congress has approved for more than 4 years for human spaceflight.

Before proceeding to answer your questions, I would like to make a few observations concerning the Augustine Committee report.

The most important observation of that Committee, and the underlying concern in all deliberations on the future of U.S. Human Spaceflight, is that it has been inadequately funded for many years now. The budget projection for NASA in the next decade and beyond is inadequate to accomplish the core objectives with which NASA has been charged. The funding is inadequate to build a timely replacement for the Space Shuttle, to transport our astronauts and other international partner nations' crews to and from the International Space Station to the Earth. The Augustine Committee pointed out that a heavy lift launch vehicle would be required to have flexibility to visit the moon, near-Earth asteroids, and to develop the technology and systems required for the first human voyages to Mars.

The plan that NASA had proposed and that has been approved by the Congress is a program offering the strategic vision for human spaceflight that was demanded by Adm. Gehman and the Columbia Accident Investigation Board. It is a program worthy of our Nation. The Augustine Committee notes that at least three billion dollars per year must be added to NASA's appropriation to accomplish the mission. Even more importantly, the Committee notes that there is no other worthwhile program of human spaceflight which could be accomplished for the amount of money presently planned for NASA. Also of interest, is that the Augustine Committee stated that Mars is the ultimate destination for human exploration to the inner Solar System, but not the best first destination. Visiting the "Moon First" and following

the "Flexible Path" are both viable exploration strategies and the two are not necessarily mutually exclusive before traveling to Mars. I certainly agree with these findings of the Committee.

The choice is now plain: either we will provide the funding necessary to accomplish worthy objectives in space, or this Nation will cede its leadership on the space frontier to others. I wish to add my voice to those who say that this leadership, the result of five decades of effort purchased at the cost of nearly a trillion of today's dollars and many lives, some of them given by close friends of mine, must not be allowed simply to drift away. As a nation, as a people, we must be better than that.

I want to acknowledge the work performed by the Augustine Committee to cover these broad based subjects in such a relatively short period of time. After extensive examination of the Committee's report, I strongly agree with the majority of their findings and recommendations. However, on some of the Committee's findings, I have a different opinion.

I am not familiar with all of the aspects of the President's proposed 2011 budget nor all of the aspects of NASA's response. I agree with the Committee's recommendation that the remaining Space Shuttle flights should be launched on a schedule that is compatible with the normal procedures used for safe check out test and launch operations, which may extend the flights into 2011. We presently have a Shuttle at KSC on standby to launch on short notice, as was determined by the CA IB. If funding were available this Shuttle could easily provide cargo delivery that would certainly enhance the viability of the ISS six-person crew capability.

The Committee wisely recommends the extension of the International Space Station past 2015 to at least the year 2020. However, the ISS will never be fully and effectively utilized unless researchers of all of the ISS partner nations have the confidence that it will be supported and sustained as long as it is operationally viable and technically useful.

To have and to use this great international laboratory requires a guaranteed space transportation capability to be available as soon as possible after Space Shuttle retirement. The Committee recommends that this responsibility be removed from NASA and offered to commercial providers. Today, approximately 88–89 percent of NASA budget flows on to commercial entities.

I would like to differentiate the two subjects, Potential Commercial Cargo delivery to the ISS and Potential Commercial Government Crew delivery to the ISS. NASA has incentivized and selected two contractors to provide commercial cargo delivery to the ISS. For commercial cargo delivery, the first issue is the development of a reliable booster to low earth orbit under the COTS program, which is yet to be demonstrated. The second issue is to develop an autonomous transfer vehicle to transport cargo from the booster in low-Earth orbit (LEO) to the ISS in a safe manner that would meet the stated ISS visiting spacecraft requirements that were complied with by the European Space Agency's ATV and Japan's HTV. The development of this type of a transfer vehicle is in itself certainly is a major challenge. The European Space Agency recently delivered their first ATV payload several years later than their initial target delivery date. Japan delivered their HTV some 2 years later than their initial target date. Both government entities used considerable resources to develop their individual transfer vehicles. I certainly wish the two United States entities success in meeting their NASA milestones for cargo delivery since the ISS is dependent upon a continued supply of cargo deliveries by the partners.

With respect to commercial crew launch delivery to the ISS, I would like to recall my own experience. I have flown two *Gemini* missions on a modified *Titan II,* ICBM, booster and two *Apollo* missions, one on the *Saturn IB* and one on the giant *Saturn V.* Over the period of thirteen years at NASA, I experienced and participated in the development of high reliability boosters, spacecraft, and launch abort systems. I was a back-up pilot for the first manned *Gemini* spacecraft and spent many months in the factory and countless hours of testing in the spacecraft as it was being built and tested. I was then pilot of *Gemini VI,* the world's first rendezvous mission. On that mission, the *Titan II* first stage engines ignited and then shutdown at T=0. Wally Schira and I had the lift off signals and a fire broke out below the base of the booster. The emergency detection system and modifications that had been installed in the *Titan II* helped us to resolve the two critical failures that we experienced in that extremely short period of time. There were several black areas of the launch trajectory of the *Titan II Gemini*. They would not be acceptable today. The *Titan Gemini* program was a high-risk demonstration program.

I was the back-up commander for the second Block I *Apollo* flight and had my crew performing a similar test, in the sister spacecraft, at the same time that the *Apollo I* accident occurred and the crew died in the spacecraft fire on the launch pad. I was then back-up commander of the first Block II *Apollo* spacecraft, *Apollo V II,* and again spent considerable time in the command module which was being

built and tested. There were also numerous NASA engineers, inspectors and support technicians at the factory to facilitate this effort. This support effort was similar to the *Gemini* program, where numerous NASA engineers, inspectors and support technicians participated in the manufacturing and test at the factory. I was then the Commander of *Apollo X,* the first flight of the Lunar module to the Moon. Again, I spent an inordinate amount of time in performing test and check-out in the command module and the lunar module.

My fourth mission, I was commander of *Apollo* for the *Apollo-Soyuz* Test Program. Again, I spent considerable time for the test and check out of the *Apollo* spacecraft and a brief time in the *Soyuz* spacecraft. These flights, both as a prime and as a backup crew member were accompanied with hundreds of hours of training for each mission in different types of spacecraft simulators and mockups where numerous emergency and normal situations were simulated and resolved.

Therefore, safe reliable delivery of a government crew to the ISS involves the human rating of the launch vehicle, the spacecraft, and the launch abort system, and the successful integration of all three elements. The safety goal for the *Apollo Saturn* was from launch to LEO and safe return to the Earth 0.9999. The process of requirements, design, and construction all begin with the NASA safety and mission assurance requirements. There also has to be a process where there is not an excessive creep in requirements that would result in cost increases and launch schedule delays of the vehicles. Unfortunately, the Augustine Committee report only gave just a very brief mention of crew safety for launch, orbital, and recovery operations. Regrettably, there were no in-depth discussions of this vital issue of safe launch to orbit and return to earth of government crews.

It may be that the complexity of developing a new government crew space transportation capability, and the difficulty of conducting spaceflight operations safely and reliably, it is not fully appreciated by those who are recommending the cancellation of the present system being developed by NASA, and the early adaptation of the presently non-existent commercial government crew delivery alternatives. There seems to be some belief that if NASA would "step aside", private alternatives would rapidly emerge to offer inexpensive, safe, reliable, dependable government crew delivery space transportation at an earlier date.

Human spaceflight is the most technically challenging enterprise of our time. No other activity is so rigorously demanding across such a wide range of disciplines, while at the same time holding out such harsh consequences for minor performance shortfalls. Aerodynamics, aerospace medicine, combustion, cryogenics, guidance, and navigation, human factors, manufacturing technology, materials science, structural design and analysis—these disciplines and many more are pushed to their current limits to make it possible and just barely possible at that, to fly in space. Flight in space is very, very hard to achieve.

We've learned a lot about human spaceflight in the last five decades, but not yet nearly enough to make it "routine" in any meaningful sense of the word. As Adm. Gehman and the CA IB outlined, these flights in the past have been developmental flights and the relatively small number in the future will be the same. Thus far, it has been a government enterprise with only three nations yet to have accomplished it. Of the three, it is important to note that only the United States, where NASA set requirements had oversight with the design and development of vehicles, and commercial entities built all of the hardware and software. In the other two countries, it is government owned entities that built all of the hardware and software for their capabilities. Development of new systems is very costly, operational risks are extremely high, and commercial profitable activities are elusive. It may not always be this way, but it is that way at present.

Apart from questions of technical and operational complexity and risk, there are business issues to be considered if the U.S. is to rely upon commercial providers for government crew access to space. It is not that industry is incapable of building space systems. Far from it. It is American industry which actually constructs all of our Nation's space systems today, and carries out most of the day-to-day tasks to implement flight operations, subject to the government supervision and control which is required in managing the expenditure of public funds.

So the question is not whether industry can eventually develop government crew delivery systems and procedures to fly in low Earth orbit. It can. The relevant questions in connection with doing so commercially are much broader than that of the relatively simple matter of whether it is possible. Let us consider a few of those questions.

Absent significant government backing, will industry provide the sustained investment necessary to carry out the multi-year development of new commercial government crew delivery systems to LEO? Will industry undertake to develop such products with only one presently known customer, the U.S. Government? What happens

if, midway through the effort, stockholders or boards of directors conclude that such activities are ultimately not in the best interests of the corporation?

What happens if, during development or flight operations, an accident occurs with collateral damages exceeding the net worth of the company which is the responsible party? A key lesson from the development of human spaceflight is that safety is expensive, and the failure to attain it is even more expensive. *Apollo 1, Challenger,* and *Columbia* have shown that spaceflight accidents generate billions of dollars in direct and collateral liabilities. Who will bear this risk in "commercial" space operations? If the company, how much insurance will be required, where will it be obtained, and at what cost? If government indemnification is expected, upon what legal basis will it be granted, and if the government is bearing the risk, in what sense will the operation then be "commercial"?

When commercial government crew delivery space transportation does come about, other questions will arise. Will there be competition in this new sector, or will there be a monopoly supplier? If NASA is to contract with the first, or only, commercial government crew space transportation supplier, and if there is no price ceiling established by a government alternative, how do we ensure a fair price for the taxpayer in a market environment in which the government is the only customer for the products of a single provider? And how is a space operation "commercial" if the government is both regulatory agency and sole customer?

Leaving aside technical, operation, and business concerns, there is the matter of the schedule by which these new commercial systems are expected to come into being. The Augustine Committee has been particularly pointed in its clams that, with suitable government backing, such systems can be made before the comparable Constellation systems, Ares 1 and Orion, could be ready. Page 71 of their report offers such a claim. It further goes on to say Committee recognizes that the development of commercial services to transport crews come with significant problematic risks. Among these are that the development of this capability will distract current potential providers from the near term goal of the successfully developing commercial cargo capability. Second, the commercial community may fail to deliver a true capability in mid-program and the program would revert to NASA "Now, how could it revert to NASA when the team has been dismissed and laid off with this exercise?" It would be a disaster for our country's Human Space Flight program both technically and politically.

Are such claims optimistic? Any launch system and crew vehicle that can transport a half-dozen people to and from the ISS, and loiter on-orbit for a six-month crew rotation period while serving as an emergency crew return vehicle, is necessarily on the same order of complexity as that of the old *Saturn 1* and the *Apollo* systems. The *Saturn 1* conducted its first test flight, with a dummy upper stage, in October 1961, and finally carried a crew for the first time in October 1968. The *Apollo VII* spacecraft which carried that crew, of which I served as back-up Commander, began its own development in 1962. Thus, the Earth-orbital segment of the *Apollo* system architecture required a half-dozen years and more to complete. These developments were carried out by highly experienced teams with virtually unlimited development funds in the cause of a great national priority.

If, in the fashion of airline travel, NASA is buying a ride rather than a spacecraft, then how, by whom, and to what standards will the company's equipment and operation be certified? How is NASA to determine that the system is truly ready to fly? Does the government merely accept the claims of a self-interested provider, on the basis of possibly very limited flight experience by company pilots? We certainly do not do that for military aircraft, and even less so is this the case for civilian transport aircraft. Extensive development and hundreds or even thousands of hours of flight testing followed by operational test and evaluation by the government is required before a new military aircraft is released into operational service; I have participated in and managed this type of testing. Similarly, new civilian aircraft are subject to extensive testing involving certification of systems and subsystem, and hundreds of flights to exact certification standards before they are allowed to be put in passenger service. Will we accept less for new, "commercial" space systems which carry government astronauts, or those of our international partners? In my opinion, the Congress should certainly not accept less.

Yet, today, we do not even know what standards should exist for the certification of commercial spacecraft to carry government crew members into orbit. What entity other than NASA can establish and verify appropriate standards for human spaceflight? I will tell you that from my perspective and from the history that I have lived, these standards, like airworthiness standards, are written in other people's blood. Some of that blood was shed by friends of mine. We don't know enough, yet, about human spaceflight to relax the hard-learned standards by which we do it. And we certainly do not yet know enough to make the assumption that new and untried

teams can accomplish it on a schedule that is better than was achieved during *Apollo*.

This takes me to another point. Some of you may recall that, a few years back, I chaired the Task Force on International Space Station Operational Readiness. This task force was charged with making an independent assessment of our readiness to put crew on the ISS, and to sustain it with the transportation systems, Russian and American, which were necessary for cargo delivery and crew rotation. We did not take this matter lightly. The ISS was new, and much smaller. We did not then have the years of experience we have since accumulated in building the ISS and flying on it. Our then-recent long-duration spaceflight experience had mostly been accumulated during the Shuttle-Mir program, and Russian experience in resupplying the Mir and the earlier Salyut space stations was not unblemished. Numerous docking failures had occurred over the lifetimes of these programs, resulting not only in cargo which went undelivered but also, in one case, the collision of an unmanned Progress resupply vehicle with the Mir. And in another instance there had been a fire on Mir itself and the first crew to visit their first very small space station Salyut died after performing the D orbit maneuver to reenter the atmosphere.

These incidents and accidents gave us pause. Not because we doubted the capability of the team; the Shuttle had been flying for over fifteen years by that time, and the Russians had accumulated decades of experience in long-duration spaceflight. I've flown with them; I know how capable they are. No, our concerns were heightened by our awareness of just how careful one has to be in this most demanding of enterprises. We cannot afford to relax that vigilance today as we go forward into a new era of ISS utilization, and as we prepare once again to hopefully voyage outward from Earth, first to the moon or the asteroids and then beyond. There is a place in these plans for the contributions of commercial government crew space transportation, but not yet demonstrated, and not to the exclusion of NASA's own safety and mission requirements.

I have asked many questions in this testimony, questions which I believe must be answered if commercial government crew human spaceflight is to become viable. I believe that these questions and others yet to come can and will be answered at some date. However, America's continued leadership in space should not depend upon the nature and timing of those answers. When commercial entities have demonstrated that they can provide dependable reliable transportation to LEO, the U.S. government crews as well as partner nation crews, the government should buy it. But until that time, there should be an assured government capability to accomplish the task.

Thank you.

Senator NELSON. Thank you, General Stafford.

Our next witness is Mr. Brian O'Connor. He is Chief of Safety and Mission Assurance at NASA. He is an astronaut, a Marine colonel, will address NASA's human safety rating requirements for commercial spaceflight.

Colonel O'Connor?

STATEMENT OF BRYAN O'CONNOR, CHIEF, OFFICE OF SAFETY AND MISSION ASSURANCE, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. O'CONNOR. Thank you, Mr. Chairman.

Senator NELSON. By the way, I was liberal in my allowing General Stafford the use of time. I'm going to be a little more observant.

Mr. O'CONNOR. Yes, sir.

Senator NELSON. He's earned the right to be heard.

[Laughter.]

General STAFFORD. Thank you, Mr. Chairman.

Mr. O'CONNOR. Well, he's about four ranks higher than I am, so I'll take 4 minutes off mine.

[Laughter.]

Mr. O'CONNOR. Thank you for the opportunity to appear here today to discuss how NASA will ensure the safety of its human spaceflight missions for transport of NASA and NASA-sponsored international partner crewmembers to the International Space Station.

The President's budget request cancels the Constellation Program and funds the agency to contract with industry to provide astronaut transportation to the ISS as soon as possible, reducing the risk of relying solely on foreign crew transports. NASA will take on this new challenge with appropriate respect for our hard-learned safety lessons of the past.

As you know, the launch or recovery of a spacecraft is a very dynamic event involving tremendous amounts of potential kinetic energy. Furthermore, operations of any system in the proximity of the ISS pose their own safety integration challenges for both vehicles and the crew. Therefore, through its program management, its systems integration, human-rating design, technical checks and balance, and proactive safety culture, NASA makes every effort to address flightcrew safety in a transparent and disciplined way.

As we've been reminded by our human spaceflight accidents and close calls over the years—X–15, *Apollo,* Space Shuttle—systems integration should not be underestimated. Also, our spaceflight vehicles traditionally have been certified by NASA to carry crews in an engineering flight test environment. It's important to note that the job of validating the right set of requirements for a new crew—crewed flight system is not a simple cookie-cutter or checklist task, nor is it expected to be a one-time task. We still see, to this day, new safety issues on the Space Shuttle, after 130 flights. Therefore, we're always looking for ways to improve our risk posture by continuously questioning our assumptions, encouraging dissenting opinions, refining our models, and providing appropriate oversight and/or insight to the work of our contractors.

The first step on the road to confidence for the next ISS crew transport capability is establishing an acquisition approach for our government industry team. To support that approach, we are developing performance requirements, including safety-risk metrics and a generic set of NASA human-rating technical requirements that would applicable to any ISS-bound crew transport system. We expect to issue a request for information to industry soon to help us, and we're working closely with the FAA, because of its obvious interest in future regulatory activities for commercial human spaceflight.

To that end, the decision to transition our ISS crew members from *Soyuz* to any new vehicle will be based on confidence. This confidence will be based on a combination of NASA technical insight into the design, appropriate levels of management oversight of the development and operation, along with demonstrated capability and reliability of the components, the subsystems, and the integrated flight and ground system.

In closing, I'd like to reiterate that safety is, and always will be, NASA's first core value and that everyone in the agency is dedicated to ensuring that our astronauts are trained and equipped to safely conduct our spaceflight missions.

Chairman Nelson, I'd be happy to respond to any questions you have, or any other members, as they come.

Thank you.

[The prepared statement of Mr. O'Connor follows:]

PREPARED STATEMENT OF BRYAN O'CONNOR, CHIEF, OFFICE OF SAFETY AND MISSION ASSURANCE, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Chairman Nelson and members of the Subcommittee, thank you for the opportunity to appear before you today to discuss how NASA will ensure the safety of its human spaceflight missions for transport of NASA and NASA-sponsored International Partner crewmembers to the International Space Station.

The President's FY 2011 Budget Request for NASA

The President's budget request cancels the NASA Constellation Program and funds the Agency to contract with industry to provide astronaut transportation to the International Space Station (ISS) as soon as possible, reducing the risk of relying solely on foreign crew transports for years to come.

NASA will take on this new challenge with appropriate respect for hard-learned safety lessons of the past. NASA will use a disciplined acquisition processes to support the development, testing and demonstration of multiple commercial crew systems to the ISS that safely and dependably perform the same functions as the Russian *Soyuz* system.

The Role of OSMA in Ensuring Human Spaceflight Safety

The NASA Office of Safety and Mission Assurance (OSMA) was established in the wake of the *Challenger* accident, and provides policy direction, functional oversight, and assessment for all Agency safety, reliability, maintainability, and quality engineering and assurance activities, while serving as a principal advisory resource for the Administrator and other senior officials on matters pertaining to human spaceflight safety and mission success. As Chief of the OSMA, I report directly to the NASA Administrator. OSMA supports the activities of—but is organizationally separate from—the human spaceflight Mission Directorates and the Office of the Chief Engineer, thus providing the Administrator an independent view of the safety and effectiveness of human spaceflight designs, flight test and mission operations in addition to all other mission roles of the Agency.

Specifically, OSMA:

- Develops strategies, policies, technical requirements, standards, and guidelines for system safety, reliability, maintainability, and quality engineering and assurance;
- Establishes the applicable set of Safety and Mission Assurance (SMA) requirements for all human spaceflight programs, and, through delegated technical authority, formally approves or disapproves waivers, deviations and/or exceptions to same;
- Verifies the effectiveness of safety and mission assurance requirements, activities, and processes, and updates, cancels or changes them as time, technology and/or circumstances dictate;
- Advises NASA leadership on significant safety and mission assurance issues, including investigation of human spaceflight-related mishaps and close calls, and provides guidance for corrective actions stemming from those investigations as well as corrective actions related to ground and flight test anomalies;
- Performs broad-reaching independent assessments of human spaceflight-related activities, including formal Independent Validation and Verification of flight and ground software critical to flight crew safety;
- Oversees and assesses the technical excellence of safety and mission assurance tools, techniques, and practices throughout the human spaceflight program life cycle;
- Provides knowledge management and training in safety and mission assurance disciplines to the assigned work force; and,
- Assures that adequate levels of both programmatic and Center institutional resources are applied to safety and mission assurance functions.

Crew Safety and Human Spaceflight

The launch and recovery of a spacecraft is a very dynamic event involving tremendous amounts of potential and kinetic energy. Such events expose flight crews to

significant inherent risks in the form of a variety of potentially catastrophic hazards and survivability challenges. Further, operations of any system in the proximity of the ISS pose their own safety integration challenges for both vehicle(s) and crew. Therefore, through its program management, systems integration and human rating design, and technical checks and balance, NASA makes every effort to address flight crew safety in a transparent and disciplined way. The process analyzes and manages failure modes and effects, and strives to eliminate hazards that could harm the crew. Where hazard elimination is not practical, the design and operational concept attempts to control or at least mitigate hazards, sometimes with crew procedures, other times with extra controls on the manufacturing, test or inspection of components to minimize human error or chance of hardware/software failure. In addition, the human-rated system provides for crew survival in the presence of catastrophic events through abort or escape. As we have been reminded by all of our major human spaceflight accidents and close calls in the past, system integration, including the interrelated effects of the various flight and ground elements for accident initiation as well as hazard mitigation should not be underestimated. Spaceflight vehicles traditionally have been certified by NASA to carry crews in an engineering flight-test environment.

It is important to note that the job of validating the right set of requirements for a new crewed flight system is not a simple cookie-cutter or checklist task, nor is it expected to be a one-time task. Compliance with requirements is only part of what makes us comfortable in human spaceflight. Much of what we do in development and operations is proactive and reactive risk management. The risk of human spaceflight is inherently high, and we know from the past that we are never as smart about this business as we think we are. We still see new safety issues on the Space Shuttle after 130 flights. Therefore, we are always looking for ways to improve our risk posture by continuously questioning our assumptions, refining our models, checking our work, and providing appropriate oversight and/or insight to the work of our contractors.

Further, our history teaches us that new risks will come up during the lifecycle of any human spaceflight system. For example, any human system will require extensive iterative work in development and optimization of abort and escape capability. In the future human systems must provide the crew with a reasonable chance at a survivable outcome even when the situation is catastrophic to the flight system. In any number of human spaceflight systems developments in the past, limitations in the abort/escape systems were not known until well into the design, at which time other hazard mitigators such as added robustness or system redundancy, or extra limits to the flight envelope were laid on late in the design cycle. Late safety risks must be treated with the same discipline and respect as any early design challenges; and where safety risks can be reasonably tolerated, their acceptability must be agreed to by all four elements of NASA's governance structure: the relevant technical authority, the cognizant system safety engineer, the flight crew, and finally the program manager. We also know from organizational cultural lapses in the past that we must encourage a reliable, recognized appeal system to hear and deal with any credible voice of dissent concerning crew safety.

In the end, the decision to transition our ISS crewmembers from *Soyuz* to any new vehicle will be based on NASA leadership attaining the confidence that the new system will meet or exceed its standards and requirements, including the risk level assigned by the agency for the ISS transport mission. This confidence will be based on the combination of NASA technical insight into the design, appropriate levels of management oversight of the development and operation, verification of performance and technical requirements along with demonstrated capability and reliability of components, subsystems (including escape and abort subsystems) and the integrated flight/ground system.

Safety and Future ISS Transportation Systems

The first step on the road to confidence for the next ISS crew transport capability is establishing an acquisition approach and operations model for our government/industry team. To support that approach, we are developing performance requirements, including safety risk metrics, and a generic set of NASA human rating technical requirements that would be applicable to any ISS-bound crew transportation system. NASA's Commercial Crew and Cargo Program Office and its technical authority, in coordination with the ISS program/technical authority, has initiated an effort to determine and establish the requirements and standards (process, design and operational) that would most likely apply to industry partners when engaging in astronaut transport development and operations.

As part of that effort, NASA is investing funds from the American Recovery and Reinvestment Act of 2009 (P.L. 111–5) to develop a subset of its human rating tech-

nical requirements that would most likely apply to the specific ISS transport mission. The technical requirements would be applicable to NASA developed/operated crew transportation systems as well as industry-developed/operated crew transportation systems for use by NASA. This task is being performed by a team comprised of representatives from NASA's human spaceflight programs, the Astronaut Office, and Agency technical authorities, including the OSMA. We are also including the Federal Aviation Administration because of its obvious interest in future regulatory activities for human spaceflight. When these documents have completed internal Agency review, NASA plans to issue a Request for Information to alert all interested parties of our intent, as well as to seek industry feedback. NASA currently anticipates completing this process in calendar year 2010. When completed, these requirements documents will provide guiding principles for developing, clearing for flight, and operating any spaceflight system before it is allowed to carry NASA crewmembers. As with any complex, high risk system, the ultimate design and operational requirements are tailored to fit the mission, the design concept, and the industry partner's own standards, experience and processes. This tailoring begins preaward, but it continues into the early acquisition phases after a contract has been let.

Conclusion

In closing, I would like to reiterate that safety is, and will always be, NASA's first core value, and that everyone at the Agency is dedicated to ensuring that our astronauts are trained and equipped to safely conduct NASA's spaceflight missions.

Chairman Nelson, I would be happy to respond to any questions you or the other members of the Subcommittee may have.

Senator NELSON. Thank you, Colonel.

Dr. George Nield, the Associate Administrator for Commercial Space Transportation in the Federal Aviation Administration, and he will address the FAA's role in regulating the commercial spaceflight industry and the licensing and certification process.

Dr. Nield?

STATEMENT OF DR. GEORGE C. NIELD, ASSOCIATE ADMINISTRATOR, OFFICE OF COMMERCIAL SPACE TRANSPORTATION, FEDERAL AVIATION ADMINISTRATION

Dr. NIELD. Chairman Nelson, thank you for inviting me to participate in this hearing on commercial space transportation capabilities.

I'd like to start by briefly reviewing the role that the Federal Aviation Administration has played in regulating commercial launches over the past 25 years.

In accordance with Federal statute, the mission of the Office of Commercial Space Transportation is to ensure protection of the public, property, and the national security and foreign policy interests of the United States during commercial launch and reentry activities, and to encourage, facilitate, and promote commercial space transportation.

Our top priority is safety. Some of the ways we carry out our safety responsibilities include developing and issuing regulations, granting licenses, permits and safety approvals, and conducting safety inspections during every licensed or permitted launch.

Our safety record to date has been excellent. Since 1989, we have licensed the launch of 201 commercial vehicles without any loss of life, serious injuries, or significant property damage to the general public.

In 2004, Congress expanded our regulatory role when it approved the Commercial Space Launch Amendments Act of 2004. In response to the Act, we have issued regulations governing human spaceflight on commercial launch vehicles, making it clear that in-

dividuals participating in these flights must be fully informed of, and accept, the significant risks involved.

One of the key challenges we are facing right now involves the beginning of a new segment of the industry: suborbital space tourism. We are currently working with about a half-dozen companies that are in the process of designing, developing, and testing vehicles that will be capable of carrying people out to the edge of space. We know that not all of these companies will be successful. Some will experience technical difficulties, while others will struggle with the necessary financing. But, there are enough very capable and well-funded groups currently working on this effort that I am confident that, in the next few years, we will see multiple companies conducting several suborbital launches per week. That will mean hundreds of launches per year, with thousands of people having an opportunity to experience spaceflight firsthand.

With that background, let me speak to the FAA's approach to regulating the launch of commercial vehicles carrying humans to orbit. Certainly, the process will not be easy. These are challenging matters, not easily reducible to checklists or go/no-go criteria. But, I believe that there is enough good will, skill, and ability among the involved parties to produce appropriate government oversight and regulatory frameworks.

To begin with, the FAA already has a solid working relationship with NASA. For example, it has been decided that all of the launches for the commercial orbital transportation services, or COTS program, and the cargo resupply services, or CRS program, will be licensed by the FAA. So, as the launch operators demonstrate the ability of commercial vehicles to deliver cargo to the International Space Station, NASA and the FAA will have the opportunity to demonstrate that we can seamlessly provide the needed government oversight for cargo missions well before any commercial crew missions are scheduled.

NASA has built an unequaled body of experience carrying humans safely to and from orbit. No one has done this work better than NASA across nearly 50 years of human spaceflight. At the same time, the FAA's Office of Commercial Space Transportation has more than 25 years of experience in regulating commercial space launches. The work before us is to harness both of these assets and come up with an approach properly suited to the safety and success of the challenging missions to come.

This is an historic opportunity to put to work, side by side, decades of space operations and regulatory experience to write the next volume of American excellence in spaceflight. The FAA is excited to be part of the story.

Chairman Nelson, this concludes my prepared remarks. At the appropriate time, I would be pleased to answer any questions that you might have.

[The prepared statement of Dr. Nield follows:]

PREPARED STATEMENT OF DR. GEORGE C. NIELD, ASSOCIATE ADMINISTRATOR, OFFICE OF COMMERCIAL SPACE TRANSPORTATION, FEDERAL AVIATION ADMINISTRATION

Chairman Nelson, Ranking Member Vitter, and members of the Subcommittee:

Thank you for inviting me to participate in this hearing on commercial space transportation capabilities. I would like to start by briefly reviewing the role that the Federal Aviation Administration (FAA) has played in regulating unmanned com-

mercial launches for the past twenty-five years. I will also address our involvement in plans for private citizens to fly on commercially-operated suborbital space flights. Finally, I will speak to the issue of commercial capabilities to deliver National Aeronautics and Space Administration (NASA) crews to the International Space Station in Low-Earth Orbit and returning them safely to Earth.

The FAA's Office of Commercial Space Transportation was established by Executive Order in 1984 and was located in the Office of the Secretary of Transportation. The office was transferred to the FAA in November 1995, where today we are one of the FAA's four lines of business, along with Aviation Safety, Airports, and the Air Traffic Organization.

In accordance with Federal statute, our mission is to ensure protection of the public, property, and the national security and foreign policy interests of the United States during commercial launch and reentry activities, and to encourage, facilitate, and promote commercial space transportation. Our top priority is safety. Some of the ways we carry out our safety responsibilities include developing and issuing regulations; granting licenses, permits, and safety approvals; and conducting safety inspections during every licensed or permitted launch. Our safety record to date has been excellent: since 1989, we have licensed the launch of 201 commercial vehicles without any loss of life, serious injuries, or significant property damage to the general public.

We are also responsible for licensing the operation of launch sites or "spaceports." Since 1996 we have licensed the operation of the California Spaceport at Vandenberg Air Force Base; Spaceport Florida at Cape Canaveral Air Force Station; the Mid-Atlantic Regional Spaceport at Wallops Flight Facility in Virginia; Mojave Air and Space Port in California; Kodiak Launch Complex on Kodiak Island, Alaska; the Oklahoma Spaceport in Burns Flat, Oklahoma; Spaceport America near Las Cruces, New Mexico; and just this January, Cecil Field in Jacksonville, Florida.

In 2004, Congress expanded our regulatory role when it approved the Commercial Space Launch Amendments Act of 2004. The Act provided direction to the FAA on how to regulate launches carrying people. Noting that "space transportation is inherently risky," Congress referred to those joining the crew onboard a spacecraft as "space flight participants" rather than "passengers." Participants will fly under a policy of informed consent, which means that they must be briefed verbally and in writing about the risks involved. They will then be required to sign a document indicating that the risks have been communicated and understood. Then and only then will they be allowed to board the craft and proceed with the launch. The crew is considered to be part of the vehicle's flight safety system, so that launch operators will need to protect the safety of the crew in order to protect the public. In our implementing regulations, we identify performance requirements for environmental control and life support systems, smoke detection and fire suppression, and human factors, as well as the need for a verification program.

One of the key challenges we are facing right now involves the beginning of a new segment of the industry: suborbital space tourism. We are currently working with about a half dozen companies that are in the process of designing, developing, and testing vehicles that will be capable of carrying people up to the edge of space. We know that not all of these companies will be successful. Some will experience technical difficulties, while others will struggle with the necessary financing. But there are enough very capable and well-funded groups currently working on this effort that I am confident that in the next few years we will see multiple companies conducting several suborbital launches per week. That will mean hundreds of launches per year, with thousands of people having an opportunity to experience spaceflight firsthand.

With that background, let me speak to FAA's approach to regulating the commercial launch and reentry of commercial vehicles carrying humans to orbit.

In its final report, which was issued on October 22, 2009, the Augustine Committee noted that "Commercial services to deliver crew to low-Earth orbit are within reach," and that "while this presents some risk, it could provide an earlier capability at lower initial and life-cycle costs than government could achieve."

As compared to suborbital missions, orbital flights include a number of additional challenges. To begin with, the mission durations of orbital flights will be significantly greater than those for suborbital flights. While a suborbital flight will most likely be measured in minutes, orbital operations are typically measured in days. As a result, the period of continuous, reliable system performance that will be needed is much greater. In some cases, such as for environmental control and life support, or thermal protection systems, additional systems, or more complex systems, may be required for orbital flights.

Moreover, and of extraordinary importance, is the fact that the energy involved in going to and returning from orbit is much greater than for suborbital flights, and

in general, that means that the hazards will also be increased. Finally, most orbital missions will need to have a launch abort system to allow those on board to safely separate from a malfunctioning booster.

Questions have been raised about how the U.S. Government should address licensing and safety issues associated with commercial crew missions to the International Space Station. Certainly the process will not be easy. These are challenging matters not easily reducible to checklists or go/no-go criteria. But I believe that there is enough good will, skill, and ability among the involved parties to produce appropriate government oversight and regulatory frameworks.

To begin with, the FAA has a solid working relationship with NASA. For example, it has already been decided that all of the launches for the Commercial Orbital Transportation Services (COTS) program and the Cargo Resupply Services (CRS) program will be licensed by the FAA, and the licensing requirement is included in the respective Space Act Agreements and contracts. So as the launch operators demonstrate the ability of commercial vehicles to deliver cargo to the International Space Station, NASA and the FAA will have the opportunity to demonstrate that we can seamlessly provide the needed government oversight for cargo missions, well before any commercial crew missions are scheduled.

Second, both Agencies approach this next regulatory effort with a pair of complementary advantages. For one thing, NASA has built an unequalled body of experience carrying humans safely to and from orbit. No one has done this work better than NASA, across nearly fifty years of human spaceflight. At the same time, the FAA's Office of Commercial Space Transportation has more than twenty-five years of experience in regulating commercial space launches. Some of the aspects of FAA licensing include existing processes for determining insurance requirements and executing cross-waivers, government indemnification subject to appropriations for third-party excess claims, and the ability of the FAA to take enforcement actions (including license suspension or revocation or levying fines) if those steps are necessary to ensure compliance with license terms and conditions.

The work before us is to harness both of these assets and come up with an approach properly suited to the safety and success of the challenging missions to come. NASA brings vast know-how to the work ahead. In addition, several of the potential commercial vehicle providers bring decades of excellence in actually designing, building, and operating the hardware that has been used in our Nation's space programs. At the same time, several new developers have indicated their interest in joining the competition, and are eager to prove themselves on the launch pad and beyond. And because of Congressional foresight a generation ago for expendable launch vehicles, and more than 5 years ago for commercial human spaceflight, we have a sound regulatory foundation already in place to support our needs.

In short, this is an historic opportunity to put to work, side-by-side, decades of space operations and regulatory experience to write the next volume of American excellence in spaceflight. The FAA is excited to be a part of the story.

Chairman Nelson, Ranking Member Vitter, members of the Subcommittee, this concludes my prepared remarks. At the appropriate time, I would be pleased to answer any questions you might have.

Senator NELSON. Thank you, Dr. Nield.

Mr. Malcolm Peterson is the former NASA Comptroller, and he is going to address the practical obstacles to NASA's utilization of commercial carriers for cargo and crew, such as pricing, procurement, and contract issues.

Mr. Peterson.

STATEMENT OF MALCOLM L. PETERSON,
FORMER NASA COMPTROLLER

Mr. PETERSON. Thank you, Mr. Chairman.

I just want to point out something, that, in terms of NASA's safety record, I think I would put the Russian *Soyuz* program up against our safety record. It is not—we are not unparalleled. And it is important to remember, in this case, in this discussion that we are having, that we are talking about a commercial venture. Now, a commercial venture means that private money is at risk. It normally also means that the private venture is willing to obtain

insurance at a reasonable cost, and that it can have—in addition to investors, it can achieve bank financing to handle letter-of-credit issues and the like, of course, as it experiences its manufacturing processes.

We have the equivalent of a commercial crew capability to the Space Station right now. We have had it in the past; it's called the "Soyuz." The commercial U.S.-sourced crew carrier will be in a competitive environment with the *Soyuz.* It will pose a great challenge to them, other than the required business, if you will, from NASA, carrying government astronauts, to compete for other astronauts.

If you'll think of it, whether it has tourists or what have you, I think it will be a price-competitive environment, and the current price for *Soyuz,* I believe, is roughly $150 million for three crew. That will be a very difficult hurdle.

Now, the question that comes to me, as an old NASA comptroller is, Why are we doing this? And that question goes to the heart of the ability to sustain governmental support for a development. If you don't have a good argument for sustaining that development, it will fall apart over time. And I am deeply concerned about the investment risk that goes with this, one of which is, if I am an investor, and I'm looking at the horizon for the return on my investment, what is that horizon? The Space Station's continued existence is not assured. We are on unknown territory, in terms of the longevity of the Space Station. We have technical risks, we have programmatic risks.

One programmatic risk was seen by the last administration, which said, "Let's not fund the Space Station beyond 2015." Now, whether or not I believe that was a false canard doesn't make any difference. They were willing to say that Space Station enjoyed so little priority, that it was better for the U.S. to put its energy into beyond-low-Earth-orbit activities.

I do not know whether other governments, such as the Japanese, the Canadians, the European Space Agency or the Russians, will have similar questions as we go forward. I would not discount the possibility, nor would I discount the possibility that the investor community will look at the risks associated with this venture and want to have what, in essence, would be a guaranteed return on investment, consistent with its risk. That risk hurdle for a venture like this should be on the order of 40 to 45 percent. It is, therefore, in my opinion, a difficult case to make, that this will be a commercially successful vehicle, without extraordinary participation by the U.S. Government.

I want to say how much I enjoyed listening to General Stafford. I know all too well what the costs of human spaceflight are. They are not in design. They are in practice. They are in documentation. They are in the paper trail. They are in endless reviews to make sure we're doing the right thing. There are so many cameras down at the Cape, for every Shuttle launch, that if you were doing a practical view of how to save money, you certainly would not proceed that way. But, that is the price of human spaceflight. We do not like to kill people, and nor do I think we should.

By the way, I think commercial cargo will succeed very well. I have my doubts about commercial crew.

Thank you.
[The prepared statement of Mr. Peterson follows:]

PREPARED STATEMENT OF MALCOLM L. PETERSON, FORMER NASA COMPTROLLER

Mr. Chairman and members of the Subcommittee, thank you for the opportunity to appear today to express my views on commercial space capabilities. I have an abiding interest in the subject, and I appear before you without any interest to pull my punches. My background as a NASA program analyst for some thirty years gave me some insight about the NASA side of the issue. After my retirement, I have worked occasionally as a consultant to contractors doing business with NASA. However, I lack the intimate familiarity with the contractor side of the government-contractor relationship that only time spent in that environment can afford. This limitation should be accordingly noted, and I apologize to all concerned in the commercial space community if, inadvertently, I poorly articulate your case.

My remarks focus on the intended use of U.S. commercial space capabilities to address U.S. Governmental responsibilities under the international partnership agreement for the International Space Station. The impetus for this policy proposal was provided by the Augustine Committee's findings last year, which recommended "the development of a relatively simpler launcher and capsule designed only as a low-Earth orbit crew taxi." The costs for this development were estimated to be lower than those associated with the development of the Ares 1 launcher and the Orion spacecraft. As a commercial venture, the Committee envisioned that "at least some commercial capital must be at risk." The Committee report notes that it heard "many argue that economic efficiencies could be found by striking a better balance between the legitimate need for a NASA quality assurance and safety process on one hand, and allowing industry to execute design and development efficiently on the other." Moreover, the Committee raised the prospect that "some development costs, and a larger fraction of operating costs of a commercial crew service to low-Earth orbit could be amortized over other markets and customers."

At the outset, let me state that I do not doubt the technical ability of commercial or "commercial-like" enterprises to supply cargo and crew services for the International Space Station (ISS). Launch vehicles and spacecraft that provide cargo and crew services are already servicing the ISS. Indeed, the Russian vehicles operate in a "commercial-like" manner, with proving both cargo and crew for a price to all who can afford the bill, including some particularly hardy and wealthy private citizens. The international partnership takes full advantage of the reliability and safety of the Progress spacecraft to carry cargo; just recently, two new spacecraft became available to carry cargo, the Ariane Transfer Vehicle and Japanese HTV. The *Soyuz* carries crew to the ISS and returns them to Earth, and does so satisfactorily enough the U.S. Government deemed it acceptable a number of years ago to retire the Space Shuttle by 2010 and allow a lengthy period of time when no alternate U.S.-sourced mode of crew transportation would be available until the advent of the Orion spacecraft and its launcher, the Ares I.

With the proposed cancellation of the Constellation program, the current Administration has proffered the substitution of the *Orion,* an advanced U.S. crew capsule, with the concept advocated by the Augustine Committee, a U.S.-sourced "commercial" crew delivery and return system. This new system is said to be "a simple spacecraft with a simple mission" that by being commercially developed for the ISS mission will allow NASA to focus on the more challenging beyond-LEO missions of the future. The budget estimate for the cost to the U.S. over the next 5 years for this effort is $6 billion, a figure close enough to the Augustine Committee's finding that the program "can be viable with a $5 billion stimulus from NASA."

The concept of a U.S.-sourced simple spacecraft to address ISS mission needs is attractive to those who find it untenable for political reasons that the U.S. pay Russia for *Soyuz* launch services or for program "robustness" reasons, a reliance on a single mode for crew access. Some commentators worry that the Russians will hold us "hostage" and raise the prices for the *Soyuz* or that the U.S.-Russian relationship will sour. The political argument is, in my way of thinking, disingenuous. The program robustness concern is not, but there is no good immediate answer to the problem it raises. Both are clearly subject to the countering punch that the barn door was open previously (post-*Columbia*), is soon to be open again, and will remain open for a number of years. U.S.-sourced payloads are already launched on non U.S.-sourced launchers. Although there is some merit to the trade deficit issue, sending U.S. funds abroad to buy foreign goods and services is common practice, and the amounts sent to Russia are relatively trivial in that larger context. So, the balance of payments argument is weak. Those who obviously lack trust in the Russian enti-

ties conveniently ignore the interdependent nature of the U.S.-Russian relationship that has been in existence and will be for a number of years, for as long as the ISS is operable.

Why attempt to close the barn door at some point in the future? Is there is a concern that the crew/cargo delivery products made in Russia will develop quality defects that will escape detection and cause ISS service outages? Even if that is a real problem looming on the horizon, and I would not dismiss it as an unreasonable postulate, we are confronted with the fact that an alternative to the *Soyuz* for crew delivery will not be available for some years to come. If it is deemed an urgent problem requiring quick attention, the current commercial transportation service program proposition most assuredly is not an effective counter. A cynic might argue that the U.S. manufacturers could more speedily acquire the rights to produce the *Soyuz* spacecraft and launcher in the U.S., using build to print manufacturing and U.S. safety and mission assurance processes. Given the willingness of U.S. rocket engine manufacturers to procure Russian-sourced engines and purchase co-production rights, I wouldn't want to argue that there is no precedent for this and accordingly this is an untenable concept.

Some have argued that we should ignore the arguments of the Augustine Committee and return to the program plan for Constellation. The availability of funding for executing this plan is a matter for the Congress and Administration to decide, so I will not opine on its feasibility. However, I will acknowledge that I was a fan of the original argument for Ares I and Orion. The program plan was based on the "leapfrog" logic. Effectively, this stemmed from a finding that there was little merit in producing a *Soyuz* wannabe. Hence, U.S. Government investment would be better spent for a more complex, capable design. The Orion and Ares I would receive the design maturation benefit for both spacecraft and launcher from undertaking LEO missions to the ISS, and then the additional incremental investment—for a better-outfitted Orion and the Ares V—would build on that experience to go to beyond-LEO missions. The problem the Bush Administration had with the plan was its affordability, unless the Shuttle expenditures could be ended, thus avoiding a further $3 billion per year increase to the projected NASA budget increases already envisioned in the outyears. Although there was some modicum of interest in a U.S.-sourced commercial cargo delivery solution, and funds were allocated to begin early work on it, there was no hesitation about relying on the *Soyuz* for crew delivery and return. As events have proven, the combination of funding constraints within NASA and normal technical challenges have led to a slip in the probability of an early Orion crewed mission to ISS by 2015. I don't know if the Augustine Committee was correct in assessing that the probable first ISS use date would be 2017, but clearly the Committee could argue cogently from past experience.

I have no quarrel with the findings of the Augustine Committee about the need for increased funding to support the logic of the original argument, or its findings that there was a great need for additional investments in research and technology required for beyond-LEO voyages. There were substantial defects in the logic of the program and budget plan NASA was saddled with by the Administration. *However I believe the nexus of their argument for developing a U.S.-sourced "commercial transport service" is grounded in their belief that there is a commercial space growth opportunity—in addition to LEO flights of crew and cargo to ISS—that can be seized by a U.S.-sourced commercial venture. This prospect will materialize only if the U.S. Government puts up the money and commits to a commercial transport service to meet its responsibilities under the ISS partnership agreement.*

I agree that there is sound logic behind the logical proposition that if: (a) the U.S. Government underwrites the bulk of the development costs and "makes the market" by committing to an annual crew delivery quota, then (b) the marginal costs—for increasing the spacecraft and launcher production rate and address operational requirements—could form the basis for a price-competitive market penetration. To follow the logic, the increased utilization of the launcher would lead to a drop in the unit cost (and increase in competitiveness, and ultimately profit margin) for the launch manufacturer. The crew spacecraft carrier would enjoy a high consumer confidence level due to NASA and FAA's involvement in its "man-rating," and additional spacecraft could be produced at marginal costs to carry (for example) tourists, all because U.S. Government funds financed the basic spacecraft production capability. It is essential for this proposition to succeed that the spacecraft be simple, yet safe, and that the U.S. governmental mission requirements be constrained in scope to avoid higher unit production costs for bells and whistles.

I also agree that the development costs for the crew capsule will clearly be less than required to execute the more complex, capable design for Orion. The annual funding increment required to be disbursed from the Treasury will be comparatively less, an especially important consideration given the priority assigned to civil space

and aeronautics programs in the Federal budget. And, for those who favor beyond-LEO voyages, the Administration proposes Congress agree to allocate a portion of the NASA budget to research and technology development to address those needs. I am an ardent fan of this investment proposal.

Why should there be any doubt on the part of Congress that this commercial transportation services venture will result in an appropriate return on the investment both to U.S. taxpayers and private investors?

One important reason for caution is the uncertainty as to the useful service life of the new crew and cargo service spacecraft. After the retirement of the Space Shuttle, the sustainment of the ISS as a viable spacecraft is a major undertaking, presenting future maintenance, repair, and enhancement uncertainties that could impact its useful life, whether that is to 2020 or even 2028. A major uncertainty is the ability to respond to game-changing events onboard the ISS, such as crew evacuation and return to Earth, or an extended period of minimal operational capability because necessary repairs cannot be accomplished by applying available on-orbit spares, or where the orbital replacement unit required for the repair exceeds the volume or lift capacity of cargo supply vehicles.

Another uncertainty is whether the participating nations will allocate the necessary future funds to respond to future ISS operational requirements, particularly if technical or programmatic events require an unanticipated spike in funding requirements. How long will the ISS last as a mission-capable spacecraft? How long will the international partners be willing to keep operating it? This is a critical issue for private investors because the commercial model assumes the revenue stream provided by the U.S. Government is lengthy enough to ensure the profit potential from the expansion of the LEO tourist trade, the key to their receiving an adequate return on their investment.

Putting aside the engineering challenge of sustaining the ISS, we should not assume the investment community dismisses out of hand the possibility of a change in the international partners' willingness to support ISS operations over an extended period of time. I highlight this point because our nearly five decades of human spaceflight illustrate the waxing and waning priorities of governmental entities engaged in human spaceflight. And, I don't mean just the U.S. Federal Government, but also the priorities of the other ISS partners: the Federal Government of Russia, the nations supporting the European Space Agency, the Government of Japan, or the Government of Canada. To that mix, there are many others who are or will be involved in future human spaceflight, most notably the governments of China and India, and in a collective sense the United Nations. The changes in priorities over time have been driven, in my opinion, predominately by these governments assigning greater or lesser value to how its human spaceflight program contributed to national security objectives.[1]

Although the development of the ISS and its initial years of operations have promoted collaborative engagement with our former adversaries and economic competitors, the future expected return on investment for the ISS on national security grounds is uncertain. (That could change, of course, if the international partnership expanded to take in the People's Republic of China and other nations, thus increasing the value to the U.S. for remaining in this collaborative engagement and a higher priority in the U.S. Federal budget.) The arguments on other grounds—economic, and research returns for instance—for continuing to invest in the international partnership are good, but not as compelling as the national security argument as reasons for governments to stay committed.

What assurance should a prospective investor take from the historical record of governmental investments in risky ventures that would lead them to invest funds in a collaborative government and industry "commercial" venture without an insurance policy? And, would he be able to recover his investment and his foregone opportunity costs? Who would provide that insurance? And, from the Federal Government's point of view, how would including costs of insurance impact the total program costs? From my experience, I have difficulty believing that our government will make an enduring commitment to provide whatever level of resources is necessary to "make the market" and ensure an adequate return on investment for U.S. commercial suppliers of cargo and crew services. It is conceivable that the Executive and Legislative branches might agree to appropriate sufficient funding guarantees

[1] The oldest case in point is the U.S. response to the Sputnik launch and follow-on launches of cosmonauts. More recently, I am not alone in suggesting that the U.S. involvement in the International Space Station's development survived in 1993 largely due to our national security interest in keeping Russian scientists and engineers off breadlines. The Bush Administration's lack of interest in planning budgetary resources to sustain U.S. participation in ISS beyond 2015 can be viewed as an indication of the priority it assigned to ISS.

that would mitigate the investment risk. However, I would not dismiss the possibility that other nations and their commercial entities would view the U.S. Government's underwriting of the investment risk as creating the potential for an unlevel playing field in the competition for non-governmental flights, such as space tourism. I would expect them to argue that the U.S. firms' pricing must include some factor related to governmental investment cost recovery. If this is viewed by the investment community as a real threat, the financial attractiveness of the commercial venture would be further diminished and require an offsetting remedy.

The Augustine Committee "estimated that the cost to NASA of creating an incentive for industry to develop the commercial transport capability for crew . . . of between $2 billion and $2.5 billion." Another component of their total program cost estimate is the provision by NASA to bidders of a "suitable version of an existing booster with a demonstrated track record of successful flight." The fraction of the launch vehicle design, development, test and evaluation costs that would be borne by NASA was estimated to be another $3 billion. Based on material available from NASA and public sources, the $3 billion would cover the unique costs of "man-rating" the launch vehicle and associated infrastructure investments. The Augustine Committee also looked back to a historical analogy, the *Gemini* program, and reviewed its program costs, applied GDP-inflator corrections. They believed the result—$2.5 billion to $3.0 billion, in 2009 dollars—provides a sanity check on their total program cost to NASA of $5 billion. I cannot comment on the credibility of these estimates, given my lack of access information to the detailed cost estimating and financing assumptions used. However, I can provide this Committee with some thoughts based on my extensive experience with program cost and schedule estimates, the interaction with funding constraints, and the unique complications introduced by the lack of failure tolerance in the human spaceflight arena.

First and perhaps foremost, human spaceflight activities are fanatical about attention to detail and documentation of processes and products, through the phases of the hardware/software design engineering, manufacturing phase, and test and evaluation phases. The designs have to be robust, with as much margin as possible to handle off-nominal conditions with margin remaining. Changes in designs are subjected to rigorous, time-consuming reviews. The close coupling of hardware and software functionality in current vehicle designs requires an integrated analysis to ensure changes do not introduce unintended consequences. Every manufacturing discrepancy is scrutinized, and "use-as-is" buyoffs of blemished hardware are extremely low. Hardware and software are subjected to exacting tests. Unanticipated test results are reason enough to redo the large performance simulation models that engineers use to establish the anticipated vehicle response to environments. Care is taken in every possible fashion to mitigate the physical stress of ascent and descent loads and other stressful conditions on the human crew member. The high acceleration forces allowed for cargo transport to orbit are not acceptable for humans. Meetings are recorded and documented, decisions are not made in haste, and caution rules the day. Every aspect of the process, from raw material acquisition to finished product, is certified. "Off the shelf" products, designed for different environments and built to less exacting standards, are not incorporated without rigorous certification. *Everything is apprised with an eye to whether it would meet a post-failure review board's excoriating analysis.* As Gene Kranz famously said, "failure is not an option." Nonetheless, in human spaceflight, systems are designed to be sufficiently robust that there is a remedy to failure for almost every system. The "fail-operational, fail-operational, fail-safe" philosophy is incorporated wherever feasible.

How much will a human-rated crew spacecraft and launcher cost? Should the Committee accept the Augustine Committee's use of *Gemini* as an analogy as appropriate. Or, was the environment so different in the early 1960s that the cost comparison is only of limited value? We certainly know that today's world of avionics and hardware/software integration is lightyears different. I confess that I am not the person with the level of detailed knowledge required to provide this Committee with an assessment of the appropriateness of the analogy. Perhaps General Stafford, a *Gemini* crew member, can provide some insight. I would note the historical literature suggests that the cost and schedule baselines for *Gemini* cited by the Augustine Committee need to be placed in context, and used—if at all—only as adding a limited value to the discussion.

Having noted my limitations on the subject, I would point the Committee's attention to several *Gemini* attributes that give me concern about the analogy's appropriateness. First, I doubt that current program planners would accept the risk taken by the *Gemini* program designers to have only ejection seats for the three person crew. (No emergency escape rocket was provided for the crew capsule in the event of a failure of the *Titan II.*) Although General Stafford is far more informed than I am, I will hazard my opinion that the likelihood was small that the crew would

survive a failure of the launch system during all but the first seconds of the ascent. That said, it is important to understand that the *Titan II* design had one really good feature for crew safety; it used a storable hypergolic liquid propellant. This gave it a much lower explosive potential than the *Titan I, Redstone, Atlas* and *Saturn* boosters. The design is also inherently less costly. The propellant, plumbing, tankage and engines of a storable hypergolic fueled vehicle permit increased design and manufacturing tolerances, and less hazardous launch site environments than do launchers using liquid oxygen and (particularly) liquid hydrogen.

A second point from the *Gemini* literature indicates that the schedule (39 months) and cost-estimate ($2.5–3.0 billion) analogies cited by the Augustine Committee need further research to determine their appropriateness. For example, the literature points out that "man-rating the Titan ICBM required minimal changes to the basic *Titan II.* Changes were made in the interest of pilot safety (*e.g.,* system redundancies); some modifications were also necessary to ready the basic ICBM to accept the *Gemini* payload."[2] The literature does not indicate whether a separate production line was established at the Martin Company to produce the twelve man-rated vehicles, and how that impacted costs, favorably or unfavorably. The literature does indicate that the 39-month development period for *Gemini* cited by the Augustine Committee does not take into account the development schedule funded by the Air Force prior to NASA's selection. Specifically, the Air Force, building on the experience with the Titan ICBM, awarded a contract in June 1960 to the Martin Company for the *Titan II* ICBM development. Although the first *Titan II* ICBM R&D flight took place in March 1962, NASA had selected the *Titan II,* appropriately man-rated, as the vehicle of choice for *Gemini* in the Fall of 1961. The program had its development issues to overcome, although not an inordinate number of them. However, NASA maintained a fallback position to use the *Saturn I* until second state combustion instability problems were solved (jointly by the Air Force and NASA in the Spring of 1963) and a series of successful *Titan II* test flights occurred in late 1963. (It is unclear from the *Gemini* literature whether the costs incurred by the Air Force in support of the *Titan II* man-rating were funded by NASA.) The first *Gemini* qualification launch occurred in April 1984, a second qualification launch (for spacecraft qualification) occurred in January 1965, and the first *Gemini* crew was launched in March 1965. Twelve (12) *Gemini* launches in total were flown by NASA, ten of them with crew. All successful.

The Committee may also wish to examine more carefully the arguments of advocates for the commercial crew and cargo launch services proposition to the effect that benefits would accrue to the global price competition environment for existing launch vehicles (such as the Atlas V) by increasing the launch rate and thus achieving lower per unit costs. This is an argument that requires careful explication of assumptions before undue credence is given. As I noted above, the human spaceflight environment is inherently costly due to its exceedingly low tolerance of any risk and demand for exhaustive levels of documentation throughout the engineering, manufacturing, test and launch environments. Economies of scale in production environments are realized when the same processes and products are used throughout. These economies are minimized if, for instance, commercial and government customers find the increased costs of man-rated processes to be overkill. Separate production lines are a possible outcome. That is not to say there are not savings from the distribution of facility support, indirect, and overhead costs across a broader user base. There are, but the savings are insignificant unless the relatively fixed costs of engineering, manufacturing, and supply chain management are very high proportionately to the production rate.

I also worry about the credibility of the arguments put forth to the Augustine Committee and included in the report that a "better balance [can be struck] between the legitimate need for a NASA quality assurance and safety process on one hand, and allowing industry to execute design and development efficiently on the other." My experience with NASA is somewhat dated, given my departure from the agency in 2003, but I had many occasions during my tenure to listen to contractors complain about time-consuming and documentation-laden NASA reviews. Time is money, of course, and an unduly lengthy review process before a decision is rendered by NASA impedes the timely accomplishment of work. But complaints often arise when the government-contractor relationship is damaged, and the contractor believes NASA staff—civil service and support contractors—do not participate as collaborators, with a sense of shared urgency. Most frequently I found the argument was about broken promises and the need for more money. NASA program managers are not welcomed with open arms by their management when they return from discussions with contractors who need more money than the budget affords. NASA pro-

[2] Source: NASA Historical Data Book, volume II, p. 84.

gram managers often find that the contractor has different priorities when it comes to assigning the "best and brightest" to their programs. And, the same is true of NASA priorities, which change over time, again as a reflection of NASA managers striving to stretch resources across programs to meet emergent problems.

The procurement environment for cost-reimbursement contracts is inherently adversarial, of course, because NASA's abiding interest is (or should be) ensuring the public's money is expended effectively, with as much accountability as possible, and in compliance with the law and procurement regulations. Among those legal and regulatory constraints are those which address socio-economic objectives, national security objectives (*e.g.,* ITAR), financial management (Prompt Payment Act, etc.) and identification of liability. Compliance with these constraints adds costs to the contract, and reduce the contractor's flexibility.

However, the Augustine Committee's report language caused me to wonder if those who pressed the "excessive oversight" argument understood the burden placed on the government officials who must address the "insurance" responsibilities of the government. To simply state the matter, NASA does not take out an insurance policy from Lloyd's to cover the consequences of failure. These consequences include not only the out-of-pocket costs but the consequent damages to program objectives. Instead, the government "self-insures." This avoids the expenditure of public funds to pay the premiums on the insurance policy provided by a private concern. However, the concomitant responsibility placed on government officials is to assure the taxpayers that they have been diligent in reducing the probability of loss of lives, hardware, and mission accomplishment. NASA officials agree to take constructive delivery of hardware and software from contractors, and sign on the dotted line. NASA officials consent to the launch and accept the liability for failure. Hence, processes must be designed to protect against those consequences, with their scope consistent with the amount of potential loss. Smaller consequences receive less attention than larger ones. Over the course of years, we have adjusted our oversight/insight insurance plans to fit the environment of acceptable risk. After the *Challenger* and *Columbia* disasters, the hang-them-high environment led to a lower risk tolerance throughout the human spaceflight community. The costs incurred by NASA for the self-insurance policy went up accordingly. Over time, with demonstrated successes, a sense of higher confidence and trust builds up. But, the trust must be earned. The oversight and engagement levels of NASA in the commercial transportation service venture cannot start out low, in my estimation, because the trust has not yet been earned. However, as success accrues, the levels will diminish to what NASA and FAA officials agree is required to fulfill their insurance responsibilities.

In closing, let me note that during my thirty years in NASA as a program analyst, cost estimator, budget formulator and Comptroller, I became all too familiar with the internal U.S. Government debates about how much of the scarce Federal budget resources should be allocated to meet the needs of mounting human spaceflight programs. I was a member of the supporting cast to the NASA Administrators for many of those years when they met with the members and staff of this Subcommittee to explain and advocate for the Administration's priorities. As representatives of the executive branch, we were not here to express our personal and professional views of the wisdom of those policies and priorities. Your challenge was then and is now difficult: how to discern the wisdom of the Administration's program and budget plans, not only in regard to civilian government space activities, but also within the larger context of public policy across the Federal Government.

Thank you for the opportunity to testify.

Senator NELSON. Thank you, Mr. Peterson.

Mr. Michael Gass is President and Chief Executive Officer of United Launch Alliance. He's going to address a strategy and a timeline for supporting crew to LEO and the possible obstacles to such development.

Mr. Gass.

STATEMENT OF MICHAEL C. GASS, PRESIDENT AND CHIEF EXECUTIVE OFFICER, UNITED LAUNCH ALLIANCE, LLC

Mr. GASS. Mr. Chairman and members of the Subcommittee, thank you for the opportunity to appear today.

The 3,900 women and men of United Launch Alliance are honored to be able to support our U.S. Government in commercial cus-

tomers' missions with the most reliable best-value launch services with our Atlas and Delta rockets.

Formed in December 2006, United Launch Alliance is a 50–50 joint venture of the Lockheed Martin Corporation and the Boeing Company. The Formation of ULA brought together the launch industry's most experienced and successful expendable launch vehicle teams.

The Atlas and Delta expendable launch vehicles have supported America's presence in space for more than five decades, with over 1,300 launches with impressive records of mission success. And I'd like to say, our heritage also includes the Titan that General Stafford talked about.

Members may recall that the first American to orbit the Earth, John Glenn, was lifted into orbit on an Atlas rocket. Since then, the launch vehicles have evolved through innovative improvements accomplished by generations of engineers and technicians into today's expendable launch vehicle fleet. The rocket Glenn flew was used by both the Department of Defense and NASA, a concept that was right then and is available again today.

Before I get to the central questions you asked, ULA, as a commercial launch service provider, would like to offer our support for the administration's proposed plan. As I stated to the Augustine Commission, our Nation must have the constancy of purpose to have a strong human and robotics science and exploration program. The plan that's proposed transcends any one company or agency solution, and it has the ability, if executed properly, to be affordable, sustainable, and flexible.

The Administration's plan makes long-overdue investments in research, technology development, and upgrades to our launch ranges that are essential to ensuring United States remains the world leader in space.

One critical investment that will have benefits to all future national security civil and commercial space mission is in our space liquid propulsion technology. I urge members to support these important technology investments.

Plan also has the potential fostering growth in commercial space opportunities. But, I think it's important to note, given today's topic, that the consolidation of—to form United Launch Alliance was done, in part, because the commercial market projected in the late 1990s did not materialize, as was originally expected, and the remaining market was insufficient to sustain two healthy launch services providers. Therefore, we believe the Nation's human access to space should not be solely dependent on the success of future commercial markets.

Now, let me address what ULA, as a proven launch service provider, is willing, and can, do to meet the demand for human-rated launch services under the Administration's proposed commercial crew program.

The EELV rockets provide the quickest and safest approach to closing the gap following the retirement of Space Shuttle. ULA believes there is a unique opportunity for NASA and the DOD to leverage the existing EELV systems toward meeting NASA's safety and reliability requirements for all missions at lower cost. ULA

also believes that the system architecture of our EELV is extensible for future exploration beyond low-Earth orbit.

We will be working with multiple companies that will compete for services—for crew services, and we plan to provide launch services in support of their proposals. We will apply our products and teams fairly in support of all of these companies. By leveraging the billions of dollars of private capital that ULA and our member companies have invested, and utilizing the existing launch infrastructure, we can support their test flights within 3 years.

Use of EELV fosters a strong launch industrial base that enables efficient access to support numerous missions. In the past, our Nation had specific launch programs that served niche payload markets, and separate systems for NASA and DOD, each requiring separate infrastructure and industrial capabilities. This was inefficient and less reliable.

In regards to the human-rating questions: Can a EELV be human-rated to support commercial crew? The simple answer is, "Absolutely." How quickly could these rockets be ready for human-rated flight? The rocket will be ready before the crew vehicle, primarily because the rocket already exists and is flying.

The Atlas and Delta EELVs were designed, from the outset, with the primary goal of being as safe, as reliable as we possibly could make them for our customers. EELVs are tasked with launching the most sophisticated, highest priority, national security satellites. They also must get to orbit safely.

What does it take to human-rate EELVs? Crew safety must be treated as an integrated solution between the crew vehicle, an inherently safe launch vehicle, and combined with a robust abort capability. ULA believes changes to the rocket are minimal. The basic rocket itself would remain the same, and we would add emergency detection systems that would provide the crew vehicle the necessary information to trigger a safe abort, if needed. ULA looks forward to the opportunity to work with NASA to validate our approach.

On-the-ground pad modifications would be—need to be made, primarily to accommodate crew egress—ingress and egress to the rocket. The cost and complexity of these facility changes are relatively modest to the existing launch complexes, but, depending on flight rates, dedicated human-launch facilities should be considered.

In summary, ULA supports the Nation's human spaceflight program and stands ready to assist in making it successful. EELV-based solutions provide a near-term, reliable solution for flying humans to low-Earth orbit. Use of the EELV fleet promotes synergy with national security space community, provides NASA with scalable options for heavy-lift exploration needs, and provides a foundation for U.S. space launch industrial base to prove its international competitiveness.

Thank you again for inviting me. I look forward to you questions.

[The prepared statement of Mr. Gass follows:]

PREPARED STATEMENT OF MICHAEL C. GASS, PRESIDENT AND CHIEF EXECUTIVE OFFICER, UNITED LAUNCH ALLIANCE, LLC

Mr. Chairman and members of the Subcommittee, thank you for the opportunity to appear today to discuss the Administration's plans for human spaceflight. My name is Michael Gass and I am the President and Chief Executive Officer of United Launch Alliance. The 3,900 women and men of United Launch Alliance are honored to be able to support our customers' missions with the most reliable, best value launch services with our Atlas and Delta rockets. Our customers are the Department of Defense, the National Reconnaissance Office, NASA, and commercial satellite system providers.

Formed in December 2006, United Launch Alliance, LLC is a 50/50 joint venture of Lockheed Martin and The Boeing Company. The formation of ULA brought together the launch industry's most experienced and successful launch vehicle teams to support the United States Air Forces' Evolved Expendable Launch Vehicle program (EELV) with the Atlas V and Delta IV products. We joined together as one company, one team, to enable the business sustainability to deliver improved mission success with lower cost to our customers.

The Atlas and Delta expendable launch vehicles have supported America's presence in space for more than five decades, with over 1,300 launches and an impressive record of mission success. These missions have carried a variety of payloads including national security, communications, navigation, weather, science, and commercial space that protect and improve life on Earth, as well as further our knowledge of the universe.

Members may recall that the first American to orbit the Earth, John Glenn, was lifted into orbit on an Atlas rocket. Since then, the launch vehicle has evolved through innovative improvements accomplished by generations of engineers and technicians to today's EELV fleet. The rocket Glenn flew was used by both the Department of Defense and NASA for human spaceflight, a concept that was right then and is available again today.

Before I get to the central questions you asked, ULA, as a commercial launch service provider, would like to offer our support for the Administration's proposed plan. As I stated to the Augustine Commission, our Nation must have the constancy of purpose to have a strong human and robotic science and exploration program. This program must transcend any one company or agency solution, and the implementation must be affordable, sustainable and flexible.

The Administration's plan makes long-overdue investments in research, technology and upgrades to our launch ranges that are essential to ensuring the United States remains the world's leader in space. One critical investment that will have benefits to all future national security, civil and commercial space missions is in space liquid propulsion technology. I urge members to support these important technology investments.

The plan also has the potential to foster and grow commercial space opportunities. I think its important to note, given today's topic, that the consolidation to form ULA was done in part because the commercial market projected in the late 1990s did not materialize as was originally expected and the remaining market was insufficient to sustain two healthy launch service providers. Therefore, we believe the Nation's human access to space should not be dependant on the success of a future adjacent commercial market.

Now let me address what ULA, as a proven launch service provider, can do to meet the demand for human-rated launch services under the Administration's proposed commercial crew program.

First, I'd like to say that ULA is ready, willing and able to support the human spaceflight program and help make it successful.

The EELV rockets provide the quickest and safest approach to closing the gap following the retirement of the Space Shuttle. ULA and our member companies have invested billions of dollars of private capital into these systems that can be leveraged for our Nation's human access to space.

ULA believes there is a unique opportunity for NASA and the DOD to leverage the existing EELV systems toward meeting NASA's safety and reliability requirements for all missions at lower costs.

ULA also believes the system architecture of our EELVs is extensible for future exploration beyond low earth orbit by either leveraging the potential fuel depot technologies or by building heavy lift vehicles using the same modular concept that is inherent in our existing EELV fleet.

We will be working with multiple companies to provide launch services in support of their commercial crew services. We will apply our products and teams fairly in

support of all these companies. By leveraging our investments and utilizing existing launch infrastructure we can support test flights within 3 years.

Use of EELV fosters a strong launch industrial base that enables efficient access to support numerous mission needs. In the past, our Nation had specific launch programs that served niche payload markets and separate systems for NASA and DOD, each requiring separate infrastructure and industrial capabilities. This was inefficient and less reliable.

Human-rating EELVs

Can EELVs be human-rated to support commercial crew?

The simple answer is absolutely.

How quickly could these rockets be ready for a human-rated flight?

The rocket will be ready before the crew vehicle—primarily because the rocket already exists and is flying.

Let me explain further. The Atlas and Delta EELVs were designed from the outset with the primary goal of being as safe and as reliable as we could possibly make them for our customers. EELVs are tasked with launching the most sophisticated, highest priority national security satellites. The value of these assets to decision-makers, the intelligence community and the warfighter far outweighs their replacement cost. They *must* get to orbit safely. As a result, all that can be done to ensure mission success is done. Any additional NASA human rating requirements that enhance the launch vehicles reliability would benefit our national security customer's missions and we would incorporate these changes in the entire fleet.

What does it take to human-rate EELVs?

ULA believes changes to the rocket are minimal. The basic rocket itself would remain the same and we would add an Emergency Detection System (EDS). The EDS is essentially an electronics box that monitors the health of the rocket as it is flying and provides the capability for the crew vehicle to trigger an abort, if needed. Crew safety must be treated as an integrated solution between the crew vehicle and an inherently safe launch vehicle, combined with a robust abort capability. ULA looks forward to the opportunity to work with NASA to validate our approach.

On the ground, pad modifications would need to be made, primarily to accommodate crew ingress and egress to the rocket. The cost and complexity of these facility changes are relatively modest. Depending on expected flight rate, dedicated human launch facilities will be considered.

In summary, ULA supports the human spaceflight program and stands ready to assist in making it successful. EELV based solutions provide a near term, reliable solution for flying humans to low earth orbit. Use of the EELV fleet promotes synergy with the national security space community, provides NASA with scalable options for heavy lift exploration needs and provides a foundation for U.S. space launch industrial base to improve its international competitiveness.

Thank you again for inviting me to testify. I look forward to your questions.

Senator NELSON. Thank you, Mr. Gass.

Frank Culbertson, Jr., is the Senior Vice President and Deputy General Manager of the Advanced Programs Group of Orbital Sciences. He is also an astronaut, and he will discuss Orbital's role in the crew development capabilities.

Mr. Culbertson.

STATEMENT OF FRANK L. CULBERTSON, JR. (CAPTAIN, USN, RET.), SENIOR VICE PRESIDENT AND DEPUTY GENERAL MANAGER, ORBITAL SCIENCES CORPORATION, ADVANCED PROGRAMS GROUP

Mr. CULBERTSON. Thank you, Mr. Chairman, and good afternoon. And, Senator Hutchison, good to see you again.

I appreciate the opportunity to participate in this hearing regarding commercially-developed crew delivery to low-Earth orbit. I'm truly humbled to be a part of such an esteemed panel. I'm sitting here between two presidents, at least one Ph.D., a financial guru, and a couple of my heroes, including the General. So, it's nice to be a part of this company, and I hope I can shed some light on

what Orbital Sciences intends to do to support the programs, going forward.

As you know, Mr. Chairman, when you put on the suit and get in the spacecraft, you have to depend on a lot of people to make sure that things are going to go right. Those of us that do that are oriented toward achieving mission success through thoughtful management of risk. Everyone who flies has the utmost confidence that the dedicated men and women of the NASA contractor team do everything humanly possible to ensure crew safety. That fact must not change as new programs and goals are developed for human spaceflight, including in the commercial world.

At Orbital, I'm responsible for oversight of our programs relating to human spaceflight, including not only cargo resupply and the Signa Spacecraft, with its Taurus II launch vehicle, but also the development of the Orion launch abort system for the Constellation Program, a key element of any spacecraft with humans on board.

In addition to our 28 years of work in other areas of spaceflight, such as satellites and launch vehicles, Orbital is totally committed to supporting the future of human spaceflight in this country, as well as to exploring business approaches that will continue to make space more accessible and productive for all potential users.

We have over 200 successful launches behind us, 500 successful missions, and we have 900 missions either on order or completed to date. And the company is well versed in the complexities and intricacies of flying into space.

Given the stated concern as to whether the commercial space industry is robust enough to develop reliable transportation services for crew to low-Earth orbit within a reasonable time, at a fair cost, and, most importantly, with the requisite safety margins, Orbital believes, as do I, that U.S. industry, given the right conditions, relationships, and investments, should be able to develop and demonstrate safe and reliable crew transportation systems for access to the ISS.

NASA's proposed funding of about $6 billion over the next 5 years, together with the addition of appropriate private capital, should be sufficient to enable at least one, and probably two, commercially provided crew systems to be demonstrated by 2015.

I'm confident that commercial providers and NASA can work together to establish the proper safety and performance standards, the fundamentals of which are already well established, that will enable industry to continue the current successful era of U.S. human spaceflight, both for U.S. Government missions and for other markets as they develop.

I would also expect that industry will make proper use of NASA's manpower, expertise, and physical infrastructure to enhance safety and mission success, which will help maintain and build our national competence in these areas, an important factor in motivating future generations to do the hard work required to continue to carry that leadership banner.

This effort will require close cooperation with NASA in developing full understanding and implementation of the appropriate human-rating standards, especially at the system level, as has been mentioned previously on the panel, and a robust, reliable, true escape system.

Once we have developed, tested, and certified our transportation service, I would be happy to volunteer to strap in once again for a mission to ISS. If I am not willing to join the first mission of an Orbital-developed spacecraft that I share responsibility for, then no one should be on that flight.

I mentioned that to my boss, and, in that same vein, our CEO, Dave Thompson, made it very clear to me yesterday, that if I'm going, he is too.

[Laughter.]

Mr. CULBERTSON. He just doesn't want to go without a pilot.

[Laughter.]

Mr. CULBERTSON. It's difficult to envision commercially-provided crew services being conducted entirely by industry with a hands-off approach from NASA, which is currently being debated. Nor can these commercial services be provided efficiently with traditional levels of government involvement and oversight at every turn. Rather, to be successful, commercial suppliers must work closely with NASA and other potential customers at key milestones and reviews, providing insight to the program and demonstrating the willingness to listen to the technical judgment and leadership of NASA's seasoned government-contractor human spaceflight team, much as we now do on the COTS program.

In addition, the FAA relationship must continue to grow and mature in order to establish a proper regulatory regime for commercial crew activities. Indemnification, insurance, and liability are all key elements in determining how we go forward. This is serious business, and the appropriate balance of insight and oversight are mandatory, as are open, transparent communications with the customer.

Just as the Shuttle MIR program was preparation for producing the collaboration and joint operations being used so successfully in the ISS program, COTS is providing superb learning experiences, not only for developing new hardware that can fly to the Station safely, but also the operations concepts, the relationships, and the lines of communication that will enable all sorts of commercial endeavors in the future. The challenge is to develop and operate commercial low-Earth Orbit transportation systems that will service not only the U.S. Government, but also the other markets that can be imagined.

Since 2008, Orbital has been fully-engaged as one of the two companies to provide delivery of cargo to ISS. We have made steady and valuable progress in that short time. We expect to have achieved all but three of 21 NASA program milestones by the end of this year, including successful completion of the critical Phase One and Phase Two safety review milestones.

The first launch of our *Taurus II* rocket from Launch Pad 0–A at the Mid Atlantic Regional Spaceport on Wallops Island, Virginia, will occur next year. This progress is aided by the hard work and cooperation of many talented people at NASA headquarters at several NASA centers, as well as the FAA, the support of Virginia and Maryland, through Mid Atlantic Regional Spaceport Authority, the efforts of our teammates, suppliers, international providers, and the internal corporate support we receive to resource this program. Please note the addition of State and local agencies and organiza-

tions in their new roles and levels of investment, a key ingredient in achieving commercial goals.

Extension of the International Space Station is one of the cornerstones of a sound future in space, both scientifically and commercially, as we strive for more distant destinations and new technologies continue to be developed.

Based on my personal experience onboard the Station, I firmly believe that the ISS is an ideal platform for development and simulation of the operations, technologies, and techniques to execute more ambitious and lengthy missions to the Moon, Mars, and other destinations. While onboard, I often imagined what it would be like to take that station and fly it to Mars or place it on the surface of the Moon. What else would I need beside what I had? In addition to a regenerative life support system and better radiation, I needed a reliable supply line or else a heck of a lot more room. But, we have to have the support of our commercial industry in order to keep that station going.

We can simulate missions to Mars, simulate missions to the Moon, and evaluate the technologies that are going to be developed to allow us to go further on that station. Extending it to 2020 is the right thing to do, and we support it fully.

In closing, please allow me to mention that, as an astronaut and a manager, I've had the privilege of working on a variety of missions which generated vigorous debate as to their advisability and even their safety. But, in the end, the right decisions were made to enhance our national security, extend international cooperation in space science, and increase the capabilities of the International Space Station.

Clearly, the NASA budget that was recently delivered by the Administration has generated a firestorm of discussion that is rarely seen on the topic of space exploration. I sincerely feel the pain of some who are at the center of the storm, as well as those who feel threatened by elements of the budget.

But, I welcome the fact that, finally, we are having a broad and fervent debate on the Nation's future in space. I know that a lot of energy is being expended at NASA to provide increased specificity of the goals. So, I am hopeful that a thoughtful and thorough examination of the available paths forward will result in an ambitious, sound set of programs that will both maintain our leadership in space exploration and inspire and challenge us as a Nation to attack even tougher problems.

Like this hearing, promoting meaningful dialogue within the relatively small but passionate group of people who truly understand and care about what it actually takes to execute what so many take for granted—that is, reliable access to space—will help move us in the right direction. And I expect the U.S. industry to support these next challenging national space endeavors, as it always has, with professionalism, excellence, and innovation.

Our Nation continues to inspire people throughout the world with our commitment to freedom, creativity, exploration, and commerce. Opening the right doors for industry to participate more broadly on a commercial basis will help maintain and enhance America's leadership on the space and economic frontiers.

Thank you again for inviting me to appear before this panel, and I'd be happy to answer any questions.

[The prepared statement of Mr. Culbertson follows:]

PREPARED STATEMENT OF FRANK L. CULBERTSON, JR. (CAPTAIN, USN, RET.), SENIOR VICE PRESIDENT AND DEPUTY GENERAL MANAGER, ORBITAL SCIENCES CORPORATION, ADVANCED PROGRAMS GROUP

Good afternoon Chairman Nelson and Ranking Member Vitter, and members of the Subcommittee. I appreciate this opportunity to participate in this hearing regarding the potential of commercial crew delivery capabilities to low Earth orbit to enhance our Nation's progress in space exploration and development.

I am honored to sit on this distinguished panel with industry colleagues Michael Gass and Gwynne Shotwell, and former NASA colleagues George Nield, now with the FAA, and Malcolm Peterson, formerly NASA's comptroller. Needless to say, it is also an honor to sit alongside two fellow astronauts whom I hold in the highest regard: Lt. General Thomas Stafford, who commanded the vital *Apollo 10* lunar landing dress rehearsal mission and 35 years ago blazed a trail for U.S.-Russian cooperation in space while commanding the American side of the *Apollo-Soyuz* mission, and Bryan O'Connor, a veteran of two Space Shuttle missions and since 2002 the NASA leader and agency conscience on all matters regarding mission safety.

For those of us who have had the great privilege to fly into space wearing the U.S. flag on our space suit—including the chairman of this subcommittee—I think it is fair to say that we are oriented toward achieving mission success through thoughtful risk taking. Every time I have entered the Space Shuttle preparing for flight it was with the utmost confidence that the dedicated men and women of NASA and its contractor teams had done everything humanly possible to ensure my safety, and I'm certain my colleagues share this view about their experiences.

My job at Orbital Sciences Corporation includes oversight of all programs relating to Human Space Flight Systems, including not only our Cargo Resupply Services contract and the Cygnus Spacecraft, with a close connection to our Taurus II Launch Vehicle, but also the development of the Orion Launch Abort System under the auspices of the Constellation Program. In addition to our 28 years of work in other areas of spaceflight, such as satellites and launch vehicles, our company is totally committed to supporting the future of human spaceflight in this country, as well as to exploring business approaches that will continue to make space more accessible and productive for all potential users.

The recent CCDev procurement competition, with 36 bidders listed, indicates that a number of U.S. companies, large and small, with outstanding track records of providing NASA with launch and space services have an interest in supporting commercially provided crew transportation services.

NASA's proposed funding of about $6 billion over the next 5 years, together with the addition of appropriate private capital, should be sufficient to enable at least one and probably two U.S. commercially-provided crew systems to be demonstrated by the year 2015.

I am confident that NASA can work with commercial providers to establish the proper safety and performance standards and oversight measures, the fundamentals of which are already well-established, that will enable industry to continue this successful era of U.S. human spaceflight for both U.S. Government missions, and for other markets as they develop. I would also expect that industry will make proper use of NASA's manpower, expertise, and physical infrastructure to not only enhance safety and mission success, but also to help maintain and build our national competence in these areas. Preeminence in exploratory and technical accomplishments remains as important as ever if we are to maintain our global leadership in space and continue to motivate future generations to do the hard work required to carry that banner.

Given your appropriate concern as to whether the commercial space industry is robust enough to develop reliable commercial launch services for crew to low Earth orbit within a reasonable time, at a fair cost, and, most importantly, with the requisite safety margins, let me clearly state again my response to the fundamental question of whether this model can work. Orbital believes, as do I, that U.S. industry, given the right conditions, relationships, and investments, should be able to develop and demonstrate safe and reliable crew transportation systems for International Space Station support by 2015.

Two of the important elements of ensuring safety in future transportation systems are close cooperation with NASA in developing a clear understanding and full implementation of Human Rating Standards, especially at the system level, and a robust,

reliable crew escape system. Furthermore, once such a service is developed, tested, and certified, I would be happy to volunteer to strap in once again for a mission to the International Space Station. If I am not willing to join the first mission of an Orbital developed spacecraft that I share responsibility for, then no one should be on that flight.

I would also like to emphasize the importance of partnership to the success of a commercial crew transportation program. For programs of this nature to work, especially in the NASA context, what's required is a sound, trusting relationship between—and open, honest communication amongst—the appropriate government, industry, and international partners. This is not a simple or easy task, as evidenced by the major space programs of the last 50 years, but it can be done and results in powerful accomplishments, such as *Apollo,* Shuttle, and the International Space Station.

I do not envisage commercially provided crew services being conducted entirely by industry with a hands-off approach from NASA. Nor can these commercial services be provided efficiently with traditional levels of government involvement and oversight at every turn. Rather, to be successful, commercial suppliers must work closely with NASA and other potential customers at key milestones, tests, and reviews, providing insight to the program and demonstrating the willingness to listen to the technical judgment and leadership of NASA's seasoned government and contractor human spaceflight team in a mutually productive relationship. In addition, the FAA relationship must continue to grow and mature in order to establish a proper regulatory regime for commercial crew activities. In this serious business there is no substitute for open lines of communication and the appropriate balance of insight and oversight that will lead to shared progress in 21st century space activities.

Just as the Shuttle-Mir Program was an excellent developmental program for producing the collaboration and joint operations being used so successfully in the International Space Station Program, the Commercial Orbital Transportation program and related Commercial Resupply Services program or COTS/CRS, are providing superb learning experiences for not only developing new hardware that can fly to the Station safely, but also the operations concepts, relationships, and lines of communication that will enable all sorts of commercial endeavors in the future.

Though the willingness of industry to invest their own technical and financial resources in an incipient space project is not new, just as Orbital is now doing on the COTS/CRS programs, the levels of investment and financial risks are moving in new directions. We see the opportunity for commercially provided crew transportation as an extension and strengthening of NASA's current initiatives in commercial cargo delivery that will lead to exciting new partnerships with private industry. The challenge is to develop and operate commercial low Earth orbit transportation systems that will service not only the government but also the other markets that can be imagined.

Since 2008 Orbital has been fully engaged as one of two companies contracted to provide the delivery of crew and cargo to the International Space Station. Although this has been a huge development program for a company of our size, and unprecedented in scope for a purely commercial venture between a private company and NASA, I am very pleased to report that from Orbital's perspective, and that of our shareholders, we have made steady and valuable progress. We expect to have achieved all but 3 of 21 NASA program milestones by the end of this year, including successful completion of the critical Phase One and Phase Two Safety Review milestones. We are on pace for first launch of the Taurus II rocket from Launch Pad O–A at the Mid-Atlantic Regional Spaceport on Wallops Island, Virginia, next year. This progress is possible because of the hard work and cooperation of many talented people at NASA Headquarters and several NASA centers, as well as the FAA, the support of Virginia and Maryland through the Mid-Atlantic Regional Spaceport Authority, the efforts of our teammates, suppliers, and international providers, and the internal corporate support we receive to resource this program.

I mention all of those players to highlight the point that it truly takes a complex mix of organizations to execute space missions, especially with crew involved. The mix and complexity have evolved over the last five decades, but this is still one of the most difficult and exciting endeavors known to humans, and I believe will be for some time to come. The addition of local and state agencies and organizations in new roles and levels of investment will only serve to enhance commercial opportunities for success. Executing parts of the development and operation in new and imaginative ways, while keeping the focus on safety and mission success, is our challenge for the near term, so that we not only expand our frontiers, but also give our children a space program that they can build upon—not be forced to rebuild.

For Orbital, we see the extension of the International Space Station as one of the cornerstones for a sound future in space, both scientifically and commercially, as we

strive for more distant destinations and new technologies continue to be developed. Looking forward, we believe the ability to provide cargo and crew services to the International Space Station is absolutely critical given the pending retirement of the Space Shuttle and the Administration's wise decision to continue the International Space Station's mission from 2015 to 2020 (or beyond!), thus enabling our scientists and researchers to pursue a more aggressive program of scientific research and utilization at this multi-national orbital facility. I applaud its designation as a National Laboratory. In addition, based on my personal experience on board the Station, I firmly believe that the ISS is an ideal platform for developing and simulating the operations, technologies, and techniques for executing more ambitious missions and lengthy missions to the Moon, Mars, and other destinations.

I often tried to imagine what we would need if the station were en route to Mars or were somehow placed on the moon, besides what we already had or expected to have in the future—such as regenerative life support and radiation protection—and one of the major requirements was a reliable supply line—and/or a lot more room! We at Orbital intend to be a key element in that supply line. It is indeed important to recognize that this new approach to meeting our Nation's commitment to fully utilize the International Space Station, including the designated National Laboratory portion of the facility, is part of a broader policy to advance American progress in space on a number of productive fronts.

By now turning anew to America's innovative private sector to provide crew transport to low Earth orbit, NASA will be able to invest new resources in transformative technologies that will speed our exploration path to the Moon, Mars, asteroids and other deep-space destinations. New launch vehicle propulsion, in-space operations technologies and related robotic precursor missions are just a few of these. This approach will also enable increased funding for NASA's other critical missions in earth and space sciences, thus helping us better protect life on our home planet through accelerated and expanded climate change research missions, and extend through our robotic emissaries and telescopes the profound search for evidence of life in and outside the solar system.

In closing, please allow me to mention that as an astronaut I have had the privilege of working on missions that have helped to enhance our national security, extend international cooperation in space science, and increase the capabilities of the International Space Station facility, which has just been given a new lease on life. Clearly, the NASA budget that was recently delivered by the Administration has generated a firestorm of discussion that is rarely seen on the topic of space exploration. I sincerely feel the pain of some who are at the center of the storm, as well as those who feel threatened by parts of the budget, but I welcome the fact that finally we are having a broad and fervent debate on the subject. I know that a lot of energy is being expended at NASA to provide increased specificity of the goals, so I am hopeful that a more thoughtful and thorough examination of the available paths forward will result in an ambitious, sound set of programs that will fill us all with pride. Just as you are doing by holding this hearing, promoting meaningful dialogue within the relatively small but passionate group of people who truly understand and care about what it actually takes to execute what so many take for granted—that is, reliable access to space—will help move us in the right direction. I expect that U.S. industry will support challenging national space endeavors as it always has—with professionalism, excellence, and innovation.

Our Nation continues to inspire people throughout the world for our commitment to freedom, creativity, exploration, and commerce. Opening the right doors for industry to participate more broadly on a commercial basis will help maintain and enhance America's leadership on the space frontier.

Thank you again for inviting me to appear before this important hearing today.

Senator NELSON. Thank you, Mr. Culbertson.

Ms. Gwynn Shotwell is President of SpaceX, and she will discuss SpaceX's progress and obstacles in developing crew capabilities.

STATEMENT OF GWYNNE SHOTWELL, PRESIDENT, SPACEX

Ms. SHOTWELL. Chairman Nelson, Senator Hutchison, on behalf of the 1,000—nearly 1,000 employees at SpaceX, I'm honored to be here to address the questions that you've provided.

It's probably no secret that SpaceX is fully supportive of the NASA budget and plans for commercial crew and cargo, and we're grateful for the support that this committee has provided to date.

As a fast-growing entrepreneurial U.S. launch-services provider that competes daily for both domestic and international business, having the support of Congress and the U.S. Government is vital to our success. Of the over 30-plus space launches we have currently on our manifest, NASA represents just under half of those. And so, they're a critical customer.

I'm pleased to be here today to discuss the proposed fiscal 2011 budget, and specifically their proposal to use commercial launch-service providers to bring crew and cargo to the International Space Station. Although this has been a matter of policy and law since 2004, we recognize that some still question whether the commercial space industry is up for this challenge, even with the significant support provided for in the budget. Accordingly, I want to answer three questions today, initially. First, can SpaceX develop a capability to deliver crew to the ISS? And, if so, when? Second, can SpaceX perform crew missions regularly and safely? And third, is a commercial crew program critical for the United States to explore other destinations in the solar system, such as Mars? The simple answer to each of these questions is, "yes," and I'll follow up with a few detailed remarks.

Regarding timing, SpaceX firmly believes that we can get astronauts to the International Space Station within 3 years of contract award, largely based on the fact that our Dragon capsule was designed, from the inception, to carry crew, with minor uprating from our cargo vehicle.

Since the company was founded in 2002, we have designed, developed, and successfully launched the first privately-financed liquid-fuel rocket, and we've gotten that vehicle to orbit twice in a row. Under the COTS program, we are on track to demonstrate cargo capability to the ISS within less than a year. This demonstration will then be followed by 12 commercial cargo resupply missions to the ISS. Although our Falcon 9 launch vehicle and Dragon spacecraft have been contracted to carry cargo currently, we certainly have an existing option under the COTS program to carry crew, as well.

Given that, as I mentioned earlier, both the Falcon 9 launch vehicle and the Dragon capsule have been designed, since inception, to carry—to accommodate crew. In fact, because our spacecraft must approach and berth with the ISS, many of the crew-rating criteria will have already been verified on Dragon before we get to the ISS. We are, therefore, confident that we can complete all necessary enhancements for Dragon, demonstrate Falcon 9's reliability, and be ready to fly astronauts to the Station within 3 years.

Regarding safety, SpaceX plans to fully comply with any and all safety standards set by NASA under the U.S. Government. We believe the notion that NASA would place astronauts on an unproven commercial rocket is simply and unrealistic concern. Falcon 9 and Dragon will fly numerous cargo and operational flights to the ISS before ever carrying crew. SpaceX has contracted over 24 Falcon 9 flights, some of which are Dragon flights, as well, and we're adding new missions to the manifest by the end of the month, actually.

If development problems ever arise, early in the Falcon 9 or Dragon Program, those problems have plenty of time to be resolved and demonstrate the service reliably.

Commercial vehicles are inherently reliable, as demonstrated by the long, proven heritage of the Atlas and Delta programs. There's nothing inherently unreliable about a commercial service.

There has been significant debate over what it means for a rocket to be man-rated. NASA is only now establishing commercial human-rating requirements. Notwithstanding, SpaceX designed the Falcon 9 and Dragon with all the known NASA requirements in mind. In fact, SpaceX has gone even further. For example, Falcon 9 is the only launch vehicle, foreign or domestic, that can survive the loss of any first-stage engine. This was a capability that was—that both the *Saturn I* and *Saturn V* rockets had, and they were used to save astronauts' lives.

Going forward, SpaceX will comply with any NASA-published human-rating requirements, and we look forward to engaging with the agency on crew-rating our systems. Let me be clear, as we've been criticized on this point, SpaceX is not looking for a free or easy ride, with respect to meeting NASA-imposed crew-rating criteria.

Last, some have criticized NASA's Fiscal Year 2011 budgetary vision for lacking a destination beyond low-Earth orbit. SpaceX firmly believes that using commercial crew and cargo services for LEO will free up NASA resources to focus on exploring other destinations in the solar system, such as Mars.

By engaging the commercial sector now, NASA will be developing procurement processes and techniques that will help enable the government to cost-effectively manage future exploration efforts. Specifically, if NASA relies on commercial companies like those represented here today, much the same way that the defense and national security community relies on us to protect the payloads and precious homeland and troops overseas, NASA can focus its great mind and limited financial resources on what NASA has always done best, pushing the frontier and exploring worlds beyond.

Mr. Chairman, the nearly 1,000 men and women of SpaceX appreciate your time and your attention to this matter. I'm happy to answer any questions.

[The prepared statement of Ms. Shotwell follows:]

PREPARED STATEMENT OF GWYNNE SHOTWELL, PRESIDENT, SPACEX

Mr. Chairman and members of the Subcommittee, on behalf of the nearly one thousand employees of Space Exploration Technologies (SpaceX) located in Florida, California, Texas, and elsewhere in the United States, I thank you for the opportunity to appear before you today.

SpaceX was founded by Elon Musk in 2002 because he had the foresight and first-hand knowledge of how the United States was falling behind in terms of affordable access to space. As Mike Griffin pointed out to Congress in 2003, "we desperately need much more cost effective Earth-to-LEO [low-Earth Orbit] transportation for payloads in the size range from a few thousand to a few tens of thousands of pounds. In my judgment, this is our most pressing need, for it controls a major portion of the cost of everything else that we do in space. Yet, no active U.S. government program of which I am aware has this as its goal."

When the Bush Administration released its Vision for Exploration in 2004, the decision was made to complete the International Space Station (ISS), retire the Space Shuttle in 2010, and acquire crew and cargo services to the ISS commercially and from our international partners. In order to ensure that NASA's resources would be

focused on space transportation capabilities for exploration of the Moon and Mars, the policy explicitly stated that supporting the ISS would be "separated to the maximum practical extent" from exploration missions beyond low-Earth orbit (LEO). The policy of acquiring commercial crew and cargo services to the ISS has been reaffirmed consistently by NASA, in numerous authorization bills, and Presidential national security directives.

It is important for the Committee to note that even had all of the ambitious goals of the 2004 Vision for Space Exploration been met, this country has long been on a path to dependence on the Russians—that is, if and until commercial LEO services become available. Moreover, it is a matter of policy and law that the Constellation system of *Ares/Orion* be developed and optimized (from a technical and operational perspective) for returning to the Moon and beyond, not for supporting the ISS. Falcon 9/Dragon, on the other hand, has been designed and optimized to replace the Russian *Soyuz* system with an improved U.S. capability, and therefore is much less complex and significantly less expensive than *Ares/Orion*.

SpaceX is grateful for all the support this Committee has provided for commercial crew and cargo services to date. As a fast-growing, entrepreneurial, U.S. provider of launch services competing daily for both domestic and international business, having the support of Congress and the U.S. government is vital to our success. This is a difficult business and we have come a long way in an unprecedented period of time. One of our key customers, of course, is NASA. I am pleased to discuss the new direction that NASA has opted to take in the proposed FY 2011 budget, specifically with respect to the agency's plans to rely upon "commercial" launch providers to develop crew delivery capabilities to LEO.

I understand the skepticism that the commercial space industry can succeed at manned carriage to the ISS within a reasonable timeframe, even with the significant support from NASA and financial investment proposed in the budget. I also understand that there are concerns about the safety of commercial vehicles. Today, I will comment broadly on these issues, with a particular focus on SpaceX's capabilities, timelines, budget, and approach to safety. To begin, however, I have two answers to questions posed by this Committee—first, in response to inquiries about the timing of commercial manned carriage, I can tell you that SpaceX firmly believes that we can be ready to fly astronauts to the ISS within 3 years after contract award. In response to questions about safety, I can tell you that SpaceX intends to be fully compliant with any and all safety standards set by NASA and the U.S. Government.

"Commercial Space" Continues to be the Best Approach for Servicing the ISS

As a threshold matter, it is worthwhile to discuss what it means to provide "commercial" services to NASA for cargo or crew carriage. This can be a confusing term inasmuch as NASA and other U.S. Government agencies rely upon the private sector for launch and other space-related service. Why are those providers not considered "commercial"?

Importantly, this is not new ground being plowed. The National Space Transportation Policy and various Federal statutes speak to the national imperative to develop and rely upon a commercial space sector. In fact, as early as 1991, the "US Commercial Space Policy Guidelines" (NSPD–3) were adopted, which stated in relevant part:

> "A robust commercial space sector has the potential to generate new technologies, products, markets, jobs and other economic benefits for the nation, as well as indirect benefits for national security. Commercial space sector activities are characterized by the provision of products and services such that: private capital is at risk; there are existing, or potential, nongovernmental customers for the activity; the commercial market ultimately determines the viability of the activity; and primary responsibility and management initiative for the activity resides with the private sector."

In the context of the newly proposed NASA budget, there is a distinction made between past and future plans focused on "commercial" providers—this distinction would appear to turn on the factors above, as well as the nature of the contracting mechanism. Specifically, "commercial contracts" are firm, fixed-price contracts that require a provider to name a price and stick to it. Additionally, payments are not made until the milestone associated with that payment is demonstrated as complete. This is hardly a novel concept, but in the space world, it has become an outlier.

Commercial also necessarily means a singular devotion to safety and reliability for manned spaceflight because, by the nature of the business, providers must com-

pete primarily on that dimension. As is true with respect to commercial aviation, businesses will fail unless safety and reliability come first, regardless of price point. The need for a laser-like focus on safety and reliability becomes even more acute when commercial space companies put their own financial skin in the game, offer services on a firm-fixed price basis against competing bidders (rather than cost-plus, "no-lose" contracts), and get paid in full only if they perform.

There are those who argue that it is unacceptable to rely upon "unproven" commercial rockets for manned carriage. This begs the question: should the Ares 1 be considered "mature" or "proven" by comparison? To date, there has been one test flight of the Ares 1–X (a four-segment solid rocket booster stage, with a fifth segment mass simulator, and an upper stage simulator) and America has invested over $8 billion in Constellation. That ratio of progress to expenditure is not particularly compelling given budget realities facing NASA and the country as a whole. And the Augustine Commission agrees that, unless NASA's budget increases dramatically, to continue along this path would be "unsustainable."

The notion that "unproven commercial rockets" would carry astronauts is an unrealistic concern by the critics of the new NASA approach. Critically, there will be many cargo test and operational flights of the Falcon 9 and Dragon before any crew flights. In addition, the demand for Falcon 9 to deliver satellites is high—at this time, there are 24 total Falcon 9 flights on the manifest. Of interest is that there are 10 of our Merlin engines on each Falcon 9. This provides a factor of ten demonstration of engine performance and life with every flight. I know of no other launch system that can cite this acceleration of life demonstration of its propulsion system. This is of great benefit to the crew program as it will leverage this accelerated spaceflight heritage.

Nonetheless, if development problems arise, there are sufficient flights to provide the opportunity to resolve any issues well in advance of astronaut transport, which stands in stark contrast to the plan for Ares 1. Separately, the Atlas and Delta vehicles, with their long-proven heritage, would actually appear to be in the front-running for manned missions. My colleagues from the United Launch Alliance will address that proposition.

Safe and reliable domestic commercial transport of cargo, spacecraft, and astronauts to low-Earth orbit (LEO) will save U.S. taxpayers significant money that can be put toward what NASA does best—pushing the frontier and exploring beyond LEO. The work must begin now, however, if the U.S. means to reduce Russian reliance at the current cost of $51 million per astronaut (and going up, it would appear based on recent comments by Mr. Perminov). Achieving a timely return to LEO after Shuttle retirement using domestic providers of launch services would incubate a commercial space market and enable NASA to move forward with technologies that take us beyond low-Earth orbit.

The Proposed NASA Budget

The President's FY 2011 budget request includes a much needed increase to the agency's top-line over the next 5 years and includes many laudable aspects such as increased investments in earth science and aeronautics, an extension and increased utilization of the International Space Station (ISS), and sustained research and development in potentially transformative technologies that should help alleviate the impact of job losses due to the successful conclusion of the Space Shuttle program and build the foundation for 21st Century solar system exploration. The budget request for exploration systems is $4.3 billion, which is up from $3.8 billion in FY 2010.

As you are aware, the Augustine Commission reviewed NASA's plans and budget and determined, among other things, that the previous plan was unsustainable absent a multi-billion dollar increase in the NASA budget going forward and that significant multi-year delays were inevitable. Assuming that there is not going to be a large and sustained increase in the NASA budget, then alternatives must be considered. Solving the LEO transportation problem with a reliable, cost-effective, domestic solution is critical to allowing the United States to devote resources that enable NASA to move forward with technologies that take us beyond low-Earth orbit.

A key fiscal fact that appears to be lost by most detractors of the NASA budget plans is that, unless there is a massive influx of funding, you cannot both fund Constellation and extend the life of the ISS beyond 2015. The ISS is an asset for which the United States has risked much. Even according to the most conservative estimates, the U.S. alone has spent upwards of $27 billion on the ISS (without factoring in any Space Shuttle-related costs). There appears to be universal support for extending its lifetime. Given this, and given the Augustine Commission's findings, it makes logical sense to pursue commercial alternatives for manned spaceflight capable of safely, reliably, and cost-efficiently carrying crew to the ISS.

SpaceX Progress to Date

SpaceX was founded just over 7 years ago, with the overriding goal of increasing the reliability of access to space and ultimately the transport of crew. SpaceX has executed at an unprecedented pace of development and success with over 30 missions on its current manifest, over $2 billion in contracts, and a customer base that spans the civil, commercial, government and international markets.

SpaceX and NASA have a strong, enduring working relationship and history, which began in late 2005 when then Administrator Griffin established the Commercial Crew/Cargo Project, later renamed the Commercial Orbital Transportation Services (COTS) program. The competitively awarded program was established to "stimulate commercial enterprise in space with opportunities for American entrepreneurs to provide innovative, cost effective access to low-Earth orbit." At the time of the announcement, and reaffirmed in numerous Presidential policies and laws, "CEV variants [later renamed Orion] for ISS or additional International Partner capabilities are backup alternatives."

To date, SpaceX has completed 16 of 22 COTS milestones and the inaugural Falcon 9 launch vehicle is currently at SpaceX's launch complex 40 at the Cape Canaveral Air Force Station (CCAFS), where last weekend we successfully completed a full systems test, including booster ignition of the flight first stage. The completion of a successful static fire is the latest milestone on the path to first flight of the Falcon 9 which will carry a Dragon spacecraft qualification unit to orbit.

In reviewing the COTS program at Congress' request, the often critical Government Accountability Office (GAO) "found NASA's management of the COTS project has generally adhered to critical project management tools and activities and the vast majority of project expenditures were for milestone payments to COTS partners." Building on the productive working relationship established through the course of the COTS program, SpaceX has subsequently been competitively awarded 12 Commercial Resupply Service (CRS) cargo missions to the ISS and been on-ramped to the NASA Launch Services (NLS) catalog. Below is a copy of SpaceX's current manifest:

SpaceX Launch Manifest

Customer	Target Date*	Vehicle	Launch Site
Falcon 9 Inaugural Flight	2010	Falcon 9	Cape Canaveral
NASA COTS—Demo 1	2010	F9/Dragon	Cape Canaveral
NASA COTS—Demo 2	2010	F9/Dragon	Cape Canaveral
NASA COTS—Demo 3	2011	F9/Dragon	Cape Canaveral
Falcon 1e Inaugural Flight	2011	Falcon 1e	Kwajalein
ORBCOMM	2011–2014	Falcon 1e	Kwajalein
MDA Corp. (Canada)	2011	Falcon 9	Cape Canaveral
NASA Resupply to ISS—Flight 1	2011	F9/Dragon	Cape Canaveral
NASA Resupply to ISS—Flt 2	2011	F9/Dragon	Cape Canaveral
DragonLab Mission 1	2012	F9/Dragon	Cape Canaveral
NASA Resupply to ISS—Flt 3	2012	F9/Dragon	Cape Canaveral
NASA Resupply to ISS—Flt 4	2012	F9/Dragon	Cape Canaveral
CONAE (Argentina)	2012	Falcon 9	Vandenberg**
Spacecom (Israel)	2012	Falcon 9	Cape Canaveral**
Space Systems/Loral (SS/L)	2012	Falcon 9	Cape Canaveral
DragonLab Mission 2	2013	F9/Dragon	Cape Canaveral
NASA Resupply to ISS—Flt 5	2013	F9/Dragon	Cape Canaveral
NASA Resupply to ISS—Flt 6	2013	F9/Dragon	Cape Canaveral
NASA Resupply to ISS—Flt 7	2013	F9/Dragon	Cape Canaveral
CONAE (Argentina)	2013	Falcon 9	Vandenberg**
NASA Resupply to ISS—Flt 8	2014	F9/Dragon	Cape Canaveral
NASA Resupply to ISS—Flt 9	2014	F9/Dragon	Cape Canaveral
NASA Resupply to ISS—Flt 10	2014	F9/Dragon	Cape Canaveral
Astrium (Europe)	2014	Falcon 1e	Kwajalein
Bigelow Aerospace	2014	Falcon 9	Cape Canaveral
NASA Resupply to ISS—Flt 11	2015	F9/Dragon	Cape Canaveral
NASA Resupply to ISS—Flt 12	2015	F9/Dragon	Cape Canaveral

*Target date indicates hardware arrival at launch site.
**Or Kwajalein, depending on range availability.

The SpaceX benchmark objective is to increase the reliability and substantially reduce the cost to access space—ultimately by a factor of ten. To that end, SpaceX is cur-

rently the only U.S. company dedicated exclusively to developing and providing end-to-end space transportation solutions, let alone ones with improvements in both cost and reliability. This focus and our devotion to minimizing critical external dependencies are key to cutting the Gordian knot that thus far has inhibited genuine commercialization of launch services.

SpaceX's unique approach of manufacturing a vast majority of the vehicle in-house in addition to integrating and providing launch services is changing the industry paradigm. SpaceX's Falcon 9/Dragon system offers a one-hundred percent American-made transportation solution. With nearly one thousand full-time personnel, SpaceX possesses deep expertise in propulsion, structures, avionics, safety, quality assurance, mission operations, launch, mission management and systems integration. Headquartered in Hawthorne, California, SpaceX also operates a state-of-the art test facility in Texas, the Falcon 1 launch facility in Kwajalein, the Falcon 9 launch facility in Florida, and an office in Washington, DC.

SpaceX has developed the capability to manufacture the majority of its launch vehicle and spacecraft in-house and is not dependent upon a single source for any key technology. This provides SpaceX with control (for price as well as quality and supply) over all key elements—from component manufacturing through launch operations. It also allows SpaceX designers to work directly with manufacturing located just steps away, streamlining the development process.

As evidence of the viability of this commercial model, in just over 7 years, SpaceX has:

- Developed, built, tested and successfully launched the Falcon 1, which included "clean sheet" development of all propulsion, structures and avionics, fully qualifying the vehicle, ground and launch support systems, and certifying a Flight Termination System with a Federal Range. The fourth and fifth flights of Falcon 1 demonstrated repeatable success in placing payloads into intended orbits;
- Developed, built and activated (with range approval) two launch sites, including all regulatory approvals and coordination. It is worthy to note that the Kwajalein facility was designed, built and activated in less than 10 months. SpaceX has completed Space Launch Complex 40 at Cape Canaveral in Florida in preparation for the maiden Falcon 9 launch;
- Developed the major Falcon 9 subsystems to a point such that the vehicle currently sits on the pad at LC–40 in Cape Canaveral, with the maiden launch of the Falcon 9 to occur in the coming weeks;
- Completed 16 of 22 performance milestones for NASA's COTS project with the first demonstration mission scheduled for 2010; and
- Competed and won 12 operational missions to resupply cargo to the ISS and completed five reviews toward two of these missions.

The Falcon 9/Dragon System was Developed to Support Crew Delivery from Day One

SpaceX is on-track to simulate delivery of cargo to the International Space Station (ISS) within a year, and return cargo to Earth. This will be followed in mid 2011 by the first of 12 commercial cargo delivery missions to ISS under the Commercial Resupply Services (CRS) contract. Although the SpaceX Falcon 9 launch vehicle and Dragon spacecraft are initially contracted to carry only cargo, they have been designed since inception to be crew-capable with minimal augmentation. This is a logical and incremental extension of cargo transportation capabilities, especially when the cargo system includes down-cargo capability (*i.e.,* return of payload to Earth).

Many functions and requirements for crew transportation are levied on the cargo vehicles by virtue of the fact that they must approach (and berth with) the ISS. Safety concerns for ISS crew, and prudent stewardship of the ISS itself, mandate that factors of safety, fault tolerance, air circulation, touch temperatures, sharp edges and many other "human rating" requirements be imposed on the cargo transfer vehicles. Accommodating crew involves up-rating of certain subsystems, adding crew monitoring and over-rides, and a launch escape system in case of booster failure during ascent.

SpaceX has been working closely with NASA through the Commercial Cargo and Crew Office (C3PO) office at JSC from the inception of the COTS program 3 years ago. The spacecraft and launch vehicle have progressed through Critical Design Review (CDR) for each of the three demonstration flights required under the COTS Space Act Agreement (SAA). At each milestone, SpaceX's designs and processes are subjected to careful, objective review by NASA through C3PO and their COTS Advisory Team of technical experts. Independent of this, the ISS program's Safety Review Panel (SRP) also review all aspects of the design that could affect the safety of the ISS and its crew. Dual-fault tolerance against critical hazards is strictly en-

forced, although no significant design changes have been required to te. SpaceX will complete Phase 2 of the 3-phase SRP process this month, with the final phase scheduled for completion in late 2010. The SRP is a critical signatory to the Certificate of Flight Readiness (CoFR), a prerequisite for the final demonstration mission which will berth with the ISS.

The augmentations required to this system in order to safely fly crew are:

- *Launch Escape System*: to provide a means for crew to safely escape from a catastrophic failure on the launch vehicle during ascent. SpaceX has identified the development of a Launch Escape System (LES) as the item requiring the longest lead time and presenting the highest technical risk;
- *Vehicle Health Monitoring System and Abort Triggers*: to continuously monitor the launch system and command the escape system if a failure is detected;
- *Life Support System*: upgrades to the existing Environmental Control System to include carbon-dioxide removal and humidity control;
- *Crew Accommodations*: including seats, pressure suits, and manual control systems;
- *Gantry Access at Launch Pad*: to provide nominal and emergency access for crew.

The above four items are the key, significant developments to up-rate the current cargo system to accommodate crew. A docking system development may also be required, or this could be provided by the government to maintain the broadest cross-compatibility between commercial transportation options. SpaceX can complete necessary augmentations and will be ready to fly astronauts to the ISS within 3 years after contract award.

Crew Safety and Human Rating

There has been significant debate over what it means for a rocket to be "man-rated." And I think it's fair to say that this term is a bit of a moving target. While NASA currently is compiling human-rating requirements to ensure astronaut safety, it has not established a certification program whereby candidate commercial vehicles will be subjected to a thorough review process focused on assuring crew safety. This said, at least with respect to SpaceX, the following facts are relevant:

SpaceX incorporated the existing NASA human rating requirements into the Falcon 9 and Dragon designs; (found in NPR 8705.2A—Human-Rating Requirements for Space Systems) and codified in the SpaceX Human-Rating Plan. This plan was presented to NASA for review as part of our first Systems Requirements Review Milestone. In May 2008 NASA released the current human rating requirements document, NPR 8705.2B, which is applicable to "crewed space systems developed by NASA," not to commercial systems. In draft form this document had an "Appendix G—Commercially Developed Space Systems" that discussed "equivalent standards," "equivalent design reviews," and participation of NASA technical authorities in design and development of new systems, or gaining their approval for existing systems. This Appendix was omitted from the released version leaving no definition for NASA human rating requirements applicable to commercial crew transportation systems.

Nevertheless, SpaceX continued to design Falcon 9 and Dragon with NASA Human-Rating standards contemplated assuming that the requirements defined for government systems such as Orion and Ares I would also apply to our vehicles. Furthermore, wherever the newer requirements were non-specific, SpaceX self-imposed the older (and in many cases more stringent) 8705.2A NASA requirements. For example, SpaceX designed its structures to meet NASA Standard 5001 Structural Design and Test Factors of Safety for Spaceflight Hardware, and SSP 30559 ISS Structural Design and Verification Requirements. Consistent with human rating standards, Falcon 9 is thereby designed to 1.4 Factor of Safety (FS) and Dragon pressurized volume and windows to 2.0 FS. Additionally, Dragon Avionics and Propulsion Systems are 2-fault tolerant to catastrophic and critical hazards. Finally, Dragon and Falcon 9 are designed to support Launch Abort System ascent and reentry loads and meet both ISS Visiting Vehicle requirements in SSP 50808 and NPR 8705.2B section 2.3.7 fault tolerance requirements. In fact, based on these requirements and available standards, the Dragon spacecraft is not expected to require any hardware modifications to the existing primary structure, propulsion, power, Command & Data Handling (C&DH), thermal control, thermal protection, communication or Entry, Descent, and Landing (EDL) subsystems. Similarly, no hardware changes are anticipated for Falcon 9 to comply with the government HRR. Both vehicles will require some additional functionality such as those listed above; however these capabilities are "keyed" into the existing design.

It is critical to note that the Falcon 9 launch vehicle is the ONLY launcher (domestic or foreign) with engine-out capability in the first stage. This feature was present on the *Saturn I* and the *Saturn V* and was leveraged to save astronaut lives in both cases.

Going forward, SpaceX will comply with any NASA-published human-rating requirements for both Dragon and Falcon 9. SpaceX looks forward to engaging with NASA to begin the Human Rating process of both these vehicles.

Current Reliance on Russian Vehicles

Though hardly news to those involved in the U.S. civil and commercial space sectors, the following facts will likely come as a disturbing surprise to most Americans: first, from 2010 through 2017, or longer, the United States will have no human spaceflight capability unless commercial services are developed; and second, during this timeframe, Russia will wield a monopoly with respect to manned carriage to the ISS. So, while the U.S. has toiled to build the ISS—risking lives with each Space Shuttle mission and expending significant national treasure to construct the orbiting laboratory—we will not be able to access the ISS without paying Russia dearly for the privilege. While these facts may be new to most Americans, they certainly are not lost on the Russians, who, despite being relatively new players in the free market economy, are proving to be quite excellent capitalists.

Russia's mastery of the relationship between supply and demand has manifested itself consistently over the past decade, but no more so than in 2007, when the United States negotiated to pay $780 million to Russia to deliver cargo and 15 crew members to the space station—six astronauts in 2009, six in 2010, and three in 2011. After the Shuttle is retired, it is not apparent what price Russia may demand for rides to the American-built portion of the ISS.

Opportunities for Growth

Initial government investment, coupled with private funds, has spurred the creation of successful new industries. For example, industries such as e-commerce, commercial aviation, and entertainment were enabled by government investment in the Internet, aviation infrastructure, and the satellite industry respectively.

U.S. Government investment in commercial space companies to create a safe, reliable, and cost effective human space transportation industry will enable the formation of entire new industries. Immediate beneficiaries of government incentives include commercial human space transportation providers, their suppliers, and local communities where new infrastructure is being developed to support new missions. As the human space transportation industry grows, the enterprise will extend to markets in scientific research, tourism, education, and exploration. With the maturation of systems, new industries will evolve in fields such as medicine, material science, energy, and expanded tourism.

Funds for this proposed commercial crew program will immediately create new high-tech jobs. The Commercial Spaceflight Federation estimated in 2009 that a $2.5 billion Commercial Crew Program would create 5,000 new jobs across the Nation. Indirect and induced job creation is typically considered to be approximately four times this number in the wider economy. Commercial crew capability for SpaceX alone, once realized operationally, is predicted to create thousands of additional direct high-skill jobs in Florida, California, and Texas.

Mr. Chairman, thank you for your support and that of this Subcommittee. I would be pleased to respond to any questions you or the other members of the Subcommittee may have.

Senator NELSON. Thank you, Ms. Shotwell.

Senator Hutchison.

STATEMENT OF HON. KAY BAILEY HUTCHISON, U.S. SENATOR FROM TEXAS

Senator HUTCHISON. Well, thank you, Mr. Chairman.

I apologize for being late, and I will have to leave after I speak. I was glad to hear some of your testimony. I have to get back to the floor, because we have the FAA reauthorization bill.

But, I'll just summarize my statement. I think many people know that I introduced legislation that would, in fact, try to continue Shuttles. I don't see how we can have a goal of keeping the Space Station open until 2020 and have a big gap, which the Chairman

and I have fought together for a long time, to not have, in a reliable capability to get crew there. So, I would like to continue the Shuttles and am certainly looking for a way to achieve that without taking away from any of the other commitments that are being made.

I have, for a long time, supported the commercial orbital transportation systems. I do certainly support commercial innovation, and I think, in the end, we will have commercial capabilities. But, I think this gap is too important to rely on just commercial and not continue our capabilities with the investment that we have made and the reliability that we have.

So, I think that, going forward, we need to go on two fronts. I think we need to explore the commercial side, and let the commercial side come forward and prove the reliability. Certainly, Mr. Culbertson, if you and your CEO are willing to go up on that first one, that would be a good test. But, I don't think we ought to shut down the Shuttle system, and particularly—it's not just the system, it's also all of the people who are necessary to keep the system safe, secure, with all of the requirements that we have for Shuttle. It's not just the flight, as all of you know. It is all of the backup that is necessary.

So, I appreciate your holding this hearing. I think it is important that we have all the information that we can. But to, I think, prematurely stop the Constellation Program and not move forward very firmly on keeping the Space Station not only open, but usable, within our own capabilities, is not good, common sense, and it's certainly not using our taxpayer dollars wisely.

Relying on Russia to fill the gap is equally, in my opinion, unreliable and unsupportable. I would rather keep our own capabilities, use our own resources for that, and invest in the commercial for the future, but only when the commercial is completely tested and ready to go.

So, that's my overview. And I hope, Mr. Chairman, that you and I will be able to begin to work on a plan that is both supportive of commercial, but also keeping the systems that we need in place to assure that America can go into space on its own, relying only on ourselves for the future, until we have the commercial vehicle or the crew return vehicles in place and ready to go.

So, thank you, Mr. Chairman, and I look forward to hearing the further questions that you will ask, as I'm sorry I have to go back to the floor.

Thank you.

[The prepared statement of Senator Hutchison follows:]

PREPARED STATEMENT OF HON. KAY BAILEY HUTCHISON, U.S. SENATOR FROM TEXAS

Mr. Chairman and Ranking Member Vitter, I appreciate your Subcommittee holding this very important hearing on commercial space capabilities. I join you in welcoming this excellent panel of witnesses.

This is the second hearing regarding the President's Fiscal Year 2011 NASA Budget proposal. I am very concerned about the direction President Obama has proposed for NASA and for human spaceflight.

If we follow the President's budget proposal, the U.S. will retire the Space Shuttle program later this year, just as the International Space Station is finally complete, without a viable U.S.-operated alternative to transport our astronauts, and International partners' astronauts, to the Space Station.

America and our partners have spent billions of dollars building and maintaining the Space Station. Now that it is complete, the Obama budget plan would ensure that the only access we have to it for at least the next several years, is by renting seats aboard Russian *Soyuz* vehicles.

Sending hundreds of millions of dollars to the Russian government and hoping they will not raise the price further, is simply the wrong approach.

Current NASA efforts for the next generation of space vehicles are already years away from completion; due in large part to underfunding that has set the Constellation program years behind schedule.

The human spaceflight gap created by these delays threatens not only our Nation's access to the International Space Station and other areas of space, but also our national security and economic interests. Under the President's proposal, America's decades-long leadership in human spaceflight will end.

The proposed budget offers a complete departure from the current approach approved twice by this committee, in our 2005 and 2008 NASA Authorization Acts. The proposal is essentially to place all of this country's human spaceflight capability in the hands of commercially-developed crew launch systems, which are not yet defined and for which no real design requirements, development milestones, or even cost estimates are provided.

The President's proposal to scrap the Constellation program and other NASA human spaceflight activities, I fear, will only intensify the space gap problem, not improve it as is claimed.

And what is most ironic is that the request proposes extending the ISS from 2015 to 2020, something I applaud and have called for myself. But, how can we support the Space Station if we have no means to get there, or to ensure it has all the spare parts and replacement equipment necessary for it to fully function through the extension?

I remind my colleagues that the planned retirement of the shuttle at the end of this year meant that 10 flights' worth of payloads destined for the Space Station, at OMB direction, and for purely budgetary reasons, were removed from shuttle flight planning and relegated to storage.

When those 10 flights were removed in 2005, the decisions about which instruments and equipment to swap into the remaining flights were based on the internal assumption of the need to support the Space Station only through 2015—not through 2020 as this committee and even the budget proposal supports.

The result of this is that we do not know how many, or which, of those grounded payload items might actually be needed in order to ensure the station can be supported and maintained safely and reliably until 2020. Not only that, we do not know which of these existing payloads are too large or too heavy to be carried to orbit by any existing vehicle other than the space shuttle.

And finally, we do not know what additional new items, or the launch vehicle capacity that might be needed to extend the life of the Space Station to 2020.

Mr. Chairman, I support commercial space flight. I continue to be a supporter of the current COTS (Commercial Orbital Transportation Systems) cargo activities being pursued with SpaceX and Orbital Sciences Corporation.

Until those efforts are proven successful and certain thresholds of required capabilities are met, we have no business making a large investment of taxpayers' dollars in the active development of crew-carrying commercial vehicles.

As of today, there is simply no assurance that commercial space capabilities are sufficiently advanced in their development to reduce the space flight gap or meet the lofty goals the President has set for the industry.

There is thus no apparent justification for the President's budget to propose complete and exclusive reliability on these proposed commercial crew capabilities.

As an alternative approach to sending up a white flag for our Nation's premiere space science agency, I have introduced legislation, S. 3068, the Human Space Flight Capability Assurance and Enhancement Act. It provides for a rational, reasoned, and mission-driven approach to the question of determining the best time to terminate space shuttle operations, based on the number of flights found to be needed to ensure space station full and safe utilization in the next several years.

This approach includes the possibility of the COTS cargo program helping to meet station requirements, once they are on-line and proven safe and effective. The legislation would also provide for accelerated replacement of government-operated human spaceflight systems to ensure we continue to have future access to space.

Unless we make every effort to close the gap in U.S. human spaceflight, we will have no choice but to face the reality that we will be totally dependent on Russia for access to space. Should Russia, far from our strongest ally, "renegotiate" the terms of our cooperation after the shuttle is retired, the U.S. could possibly be

blocked from space for years. This would leave Russia and China as the only nations in the world with the capability to launch humans into space.

I will be working with my colleagues to ensure all of these issues are put on the table for discussion. I believe we can find a more measured and reasoned approach that ensures the best use of investments we have already made, and provide the Congress and the Administration with necessary information to inform our judgments on alternative launch vehicle developments.

It is my hope that this hearing will contribute to our understanding of the commercial potential for meeting these challenges, but in a realistic and responsible manner.

I look forward to the testimony of our witnesses.

Senator NELSON. Thank you, Senator.

General from your perspective, having flown several vehicles, what assurances do you think are necessary to guarantee that these commercial vehicles are safe to fly on?

General STAFFORD. Mr. Chairman, the criteria that NASA has developed over the years in the NASA Safety and Mission Assurance has worked very well, and this has been learned over nearly five decades. And there has to be both insight and oversight and, you know, special care, before anything should ever be said it is safe, and it has to reach that three nines of reliability, sir.

Senator NELSON. And to you, Colonel O'Connor, has NASA defined a process to validate what the commercial providers are saying in compliance with human-rating requirements?

Mr. O'CONNOR. Mr. Chairman, we do have a process, that we just completed at the preliminary design review for Constellation, which includes all the same types of ingredients that you would have in a process to validate requirements and to verify that they've been met. There's one additional thing, though, and that is that we are open, as we have been with Constellation and other programs, to industry showing us that they can do something that we call out as a "shall" statement, or as a requirement, that meets or exceeds. We're open to tailoring, in other words. So, that's a piece that will be involved anytime we start a new program, including this one.

We plan to put out an RFI, here in the next month or so, and to get some feedback from industry, including any ideas they have on how they might substitute some standard or some approach that they have that they believe is as good as what we suggest in our requirement. So, that tailoring iterative back-and-forth process would go on with any new program, and it would with this, as well.

Senator NELSON. And, Mr. Peterson, is it going to take $6 billion to make this crew-ready over the next 5 years?

Mr. PETERSON. That is a great question. And I have no clue.

[Laughter.]

Mr. PETERSON. I know that it is not a *Gemini* redo. I think the example of *Gemini* is interesting. It may be the only appropriate analogy that the Augustine Commission could come up with, but it is, by no means, one that I would say was appropriate to the level of confidence required for you to appropriate funds.

Senator NELSON. How would you suggest for us to determine whether or not $6 billion is too much, too little, or just right, as we start the budgetary process?

Mr. PETERSON. Well, I don't think you can do so at this stage without numbers on the table—estimates, designs, procedures, the

whole nine yards. Our history—and it bothers me to say this, but our history is not exactly one of unparalleled excellence in cost-estimating what we have never done before. We manage to miss it, usually, by an order of magnitude or so. So, to say $6 billion is a good number, without an understanding of the program details, processes, requirements, funding commitments: all that is beyond my ability.

Senator NELSON. But, you felt fairly confident in getting cargo up on commercial vehicles.

Mr. PETERSON. I think cargo is well within our capability; we do it constantly. If you think of delivering spacecraft to orbit, we do that. We have the more—most difficult areas, which are the rendezvous and docking with the Space Station. There are systems that are now certified for doing that. I believe they would be at least GFE'd by NASA to the company. It is, I think, a relatively straightforward—not easy, but straightforward job. I think the competitive environment for cargo is such that the economies of scale, at least on the launch end, will certainly prevail. I think it's a good business case that can be made, and I would proceed with that, without any hesitation.

Senator NELSON. Mr. Gass, what would happen if the Congress decided, since the Congress controls the purse strings, that we wanted to take the $6 billion projected by the President over the next 5 years, and use that, not for human certification of the commercial vehicles, but, instead, to accelerate the R&D for a heavy-lift vehicle for the Mars program?

Mr. GASS. Well, with any major program, just as Mr. Peterson talked about, you know, the rate and thoroughness of the program is a function of how much we can afford on any given day. So, if we apply more resources to the Mars activity, I think we'll achieve that goal sooner.

The key on all of this is really keeping that balance throughout the entire industrial base. That infusion, the importance of this whole debate, is making sure that we have the constancy of purpose to keep on exploring and having that constancy of funding. How we apply it is a system-design activity. If we—whether or not we are going to low-Earth orbit as our first priority, or going to Mars as our first priority, that foundational step of propulsion investment, some of the other technologies we need to explore Mars, has to be done someday. And when we apply those funds, we'll increase our rate of achievement.

Senator NELSON. Colonel O'Connor, is the Astronaut Office involved in the certification/validation process?

Mr. O'CONNOR. Absolutely. Yes, sir. We have what we call a "four-legged stool," and we apply that four-legged stool as a governance model whenever we have what we call "residual risk." Residual safety risk, when you have human beings involved, means that we need volunteers. We don't force anybody at NASA to take residual safety risk.

The other three legs of the stool, of course, are the program manager, who gets the last opportunity to accept that risk, but only if the other three legs of the stool, which includes the safety officer, the technical authority, which is the owner of the requirement we're talking about—the particular issue always has an engineer-

ing or technical-authority owner—and then, of course, the volunteer. So, if the technical authority is OK, the safety guy is OK, the crew is happy to volunteer to take on that risk, then, and only then, is the program manager allowed to accept the risk.

Why do I bring that up? Because it happens a lot in design and development of these things and—as well as in operations. When there's a waiver, a deviation, a new issue comes up, which is a little over the risk that your volunteered to take for, just by signing up to do this job—in other words, the inherent risk of spaceflight—we quite often do have residual-risk issues that come up. And the crew office is very much a part of that, because they are the people at risk.

Senator NELSON. How have, Colonel, the Russians minimized their risk over the years? And then I'm going to ask General Stafford.

Mr. O'CONNOR. We've been working with the Russians for quite a while. General Stafford will tell you how it all started. But, in 1995 we decided that it would be a good idea to fly one of our astronauts on a *Soyuz.* We look at this as an analogy to some of what we're doing today, because we wonder, How did we get confident enough to say it's OK for our crewmember to fly on the *Soyuz*? Only recently had we really understood what was going on in their space program. You know, it had been kind of secret, there, for a while. We didn't know all the details of their design, or even of their failure history. But, in the early 1990s, it opened up, and we talked a lot with the Russians, and we sent engineers over there for about 3 years from the safety mission assurance and engineering organizations, not to lay on requirements—this is a case where we developed our confidence to put crewmember on some other vehicle that we did not design and we do not operate, and requirements, or what we're calling "the human-rating requirements," were not a part of that. We didn't lay any requirements on that system. I know that General Stafford, when they did the rendezvous in *Apollo-Soyuz,* NASA did have a couple of requirements that they put on the *Soyuz* to make it an appropriate interface when they docked. But, this was a case where we were going to either going to accept the *Soyuz* to fly Norm Thaggart, or not. And it took us a while, but we got to the confidence level we needed.

One of the key ingredients, when we didn't have requirements verification, was this business of equivalence. They did things differently than we did. We might have a requirement for failure tolerance. They didn't have it written the same way, but we looked at it, and we decided that, you know, their—they have an equivalent approach, here, even though it's not exactly like ours. And it took us a while, but we finally got comfortable with equivalence.

And then, the last ingredient, which was probably the most important for that adventure, was their demonstrated reliability. They had, I think, 67 flights in a row since their last casualty. And that's a pretty good demonstrated reliability. So, all those things added up. And in every case, we will look at the combination of insight, understanding, trust in another government organization, like we've done with HTV, ATV, *Soyuz,* and the demonstrated the reliability. And add those up to the point where we get confident enough to fly.

Senator NELSON. General Stafford, did you want to add to that? How did we achieve the confidence in the Russian system?

General STAFFORD. Yes, Mr. Chairman. You know, I started, back when it was a Soviet system, at the height of the cold war, and everything was Bolshoi—a secret. It was a big secret. But yet, in that effort, we went straight across the table with them, and they opened up to us, and we made requirements. They changed at least two valves on the *Soyuz,* some electrical issues on the *Soyuz.* And they opened up some of their—how they approached safety. As Colonel O'Connor said, it's somewhat not the same way we do, but the end product is nearly the same. And so, we were satisfied with that, and flew that.

And then, as you remember, sir, because of my former experience with the Soviets, now the Russians, I chaired the Shuttle-MIR Advisory Task Force, and had, kind of, the oversight of that, looking at safety issues. And from there, again, we looked all into the details of that. And then, now, the International Space Station, which I share the advisory panel on. So, the Russians do a very good job, and it's slightly different than ours, but yet, they end up at the same place.

Senator NELSON. All right. Let me ask you another question with regard to buying a seat on the Russian vehicle. How can we, the taxpayers, be guaranteed that the seats are going to be purchased at a fair market price?

General STAFFORD. Well, you know, the accountability in Russia is somewhat different. And it's good to see my old friend, Mr. Peterson, and he's an expert on financial affairs. But, they didn't quite understand the profit issue back in the Soviet Union; I think they certainly do now.

And it's—they have a demonstrated effort, and now it goes for approximately, I think, $50 million a seat, include all the training. And this requirement that they have to support the Station is up in the year 2012. It will probably be renegotiated. And unfortunately, the Russian rubble is appreciating while the American dollar is falling, and I do not know what it will end up as. But, how much it is subsidized, we can't tell. But, I don't know—it would be very difficult to match their price at this time, sir.

Senator NELSON. Mr. Peterson, let me ask you, with regard to American vehicles, how can we make sure the taxpayer is getting a decent price?

Mr. PETERSON. We're not going to be able, in my mind, to compete against the *Soyuz.* It is—our fair price is going to have to be a amalgam of our national interest in the venture and however we want to parse the value of being able to create a commercially viable vehicle. If it is price alone, I believe the Russians can undercut us with relative ease. I doubt that we could launch an equivalent vehicle for $150 million. I'd be surprised if we could do it for less than $400 million.

Senator NELSON. So, sounds like you're saying that, other than the national interest of having an American vehicle to fly to and from the Space Station, that, just from a price standpoint, you're suggesting we might better use that $6 billion—instead of man-rating them, to make a faster and better heavy-lift vehicle.

Mr. PETERSON. Well, I believe the issue that puzzles me is why the administration did not accept the recommendation of the Augustine Committee to continue to work on the Orion spacecraft and have that as a warm backup. The envisioned simple spacecraft that the Augustine Committee talked about, I've referred to in my written testimony, probably caustically, as a *Soyuz* "wannabe." That's a little bit acid, I agree. On the other hand, Orion leapfrogged the *Soyuz,* and we were going to prove Orion's reliability by taking it to the Space Station, getting the maturity that comes from repeated trips, and then, of course, being able to venture on to beyond low-Earth orbit.

I think I'll stop there, probably having shot myself in the foot more times than I want to count. But, thank you for offering me the opportunity.

Senator NELSON. All right.

[Laughter.]

Senator NELSON. You do that because you're a former Comptroller.

Let me turn to Ms. Shotwell and Mr. Culbertson. Please speak for your companies on that question.

Ms. SHOTWELL. I appreciate this opportunity.

I'm here to say that we can guarantee crew flights to the ISS for less than $50 million a seat.

Senator NELSON. By what year?

Ms. SHOTWELL. Three years from the time we initiate. And the reason why it sounds so quick is because the Dragon vehicle was designed, really from the outset to accommodate crew—with a number of key developments still to do, but developments that we're comfortable with.

Senator NELSON. Do you have to have all the $6 billion to develop it?

Ms. SHOTWELL. No, sir.

Senator NELSON. How much?

Ms. SHOTWELL. I'd prefer to answer that question slightly differently, if you don't mind. If you were to spend all $6 billion on a commercial crew, and everybody were to make our bid—have the same bid as ours—you would have somewhere between 5 and 10.

Senator NELSON. Between 5 and 10 what?

Ms. SHOTWELL. Five and 10 suppliers.

Senator NELSON. Mr. Culbertson?

Mr. CULBERTSON. Mr. Chairman, I don't think I can be quite that optimistic as Ms. Shotwell. But, we've looked at the previous systems that have been flown, and we've looked at how we develop spacecraft, and what it takes to ensure that they're going to be—not only accomplish their missions, but be safe and reliable.

One of the benchmarks we looked at was the development of the Shuttle itself. When you look at it on a per-pound basis, the Shuttle was about $150,000 per pound for development. If you were to take that number—and it's fairly similar for other vehicles—but, if you were to take that number for, say, a 20,000-pound vehicle that you needed to carry three to five crew to the Space Station, that works out to about—if it's a 20,000-pound vehicle, it works out to about $3 billion for development.

Given today's productivity and efficiencies that we have, we think the number could be significantly less than that. But, at least that gives you an upper bound, on a conservative approach, of what one company might need to do that level of development.

And in terms of the cost of each individual mission, I think Mr. Peterson's right, it's probably around $300- or $400 million if you're going to have all of the ancillary programmatic capabilities dealt with by the company that's providing that. A lot of it depends on how much NASA provides and how much the company provides and how much you're going to invest in mission control, launch operations, recovery operations, training, all that goes with flying humans in space. So, the number is pretty wide, in that regard.

And as far as the government investment required—for a program of this size to have that type of upfront investment and the low number of flights that are currently envisioned, you've either got to work aggressively to grow the market and ensure that you do have sufficient demand for the seats or you're going to have to have fairly significant government investment upfront in order to cover the development costs. And those are things that we're going to have to work on very hard in the future to make sure that we get into the right box.

Senator NELSON. Let me shift from crew to cargo and ask you, for commercial cargo, what lessons can U.S. companies learn from the development efforts of the ATV and the HTV?

Mr. CULBERTSON. Who's that for?

Senator NELSON. Anybody.

Mr. CULBERTSON. OK. I think we should see that as a challenge. There are other countries that are developing cargo capability ahead of us. The Russians did it a long time ago, with Progrez. ATV and HTV, though expensive and somewhat behind their original schedule, have demonstrated their capability to deliver cargo to the crew—to the Space Station semi-autonomously. I do believe it's well within the capability of U.S. industry to do that, as we and SpaceX are demonstrating, and will demonstrate concretely in the coming year.

And I think that's a capability that we should continue to build on, not only just to provide cargo, but to provide other support for the Station and other markets that come along. I think that as more and more vehicles are developed that will use space as their place of business, having the commercial world ready to support that is an important aspect of what this country ought to be able to do, whether it's servicing other satellites, repairing them, recovering them, working on orbital debris, providing access to other platforms for scientific experiments; I think that's all within the realm of our commercial industry.

Senator NELSON. Well, General Stafford, you pointed out, in your written testimony, that the Europeans and the Japanese were years behind in their schedule in delivering payloads to the Station. Is that going to happen with the rest of these folks?

General STAFFORD. Well, Mr. Chairman, I know, from the position as Chairman of the Advisory Task Force, kind of the oversight committee, that we watched that, and that 2 years-plus, and the Europeans put a lot of resources in—1.3 billion, at least—Euros—at least advertised. The Japanese, we don't know. And they put a

lot of their top engineers, resources on it, and they were over a year late. So, you know, as former Deputy Chief of Staff of the Air Force for Research, Development, and Acquisition, I've seen a lot of great forecasts come in from commercial companies—what we call the "hot biscuit" items—and they're always usually undercosted and under-schedule what really happens.

Senator NELSON. We have had two votes called on the floor. Of necessity, I'm going to recess the Committee. I'm down to the remaining 5 minutes to vote—to cast my vote on the first vote, and I will cast my vote on the next vote immediately at the beginning, and race back here.

So, the Committee will stand in recess.

[Recess.]

Senator NELSON. OK. The Committee will resume.

Dr. Nield, what do you anticipate to be the greatest challenge facing the FAA in developing appropriate regulations for ensuring public safety in commercial spaceflight operations?

Dr. NIELD. I think we have an excellent foundation, based on our assessment of what the future's going to bring. And Congress has given us some excellent guidance on how we should handle crew and how we should handle public safety, and so, we've done the best we can to set up that regulatory environment.

But, until we really see these vehicles fly, we're not going to have the demonstrated track record, we're not going to understand how well that's going to work. So, I think this transition, as we see both the suborbital space tourism-type operations in the next few years, and then, eventually, some of the orbital flights, first with the cargo, then that'll really enlighten the community, in terms of what additional, or different, regulations we might need to put into place, and it'll give people a better calibration, in terms of the overall difficulty of challenging—of satisfying some of these challenges that we face.

Senator NELSON. Well, should the FAA be involved at all, with regard to these rockets going to and from the Space Station?

Dr. NIELD. I believe we have an excellent relationship with NASA, and we need to continue to work together to figure out the best approach to take. But, I would just point at our track record to date in working through both the COTS and the CRS programs. I think we've worked together well. We've taken advantage of the FAA licensing regime and all the benefits that it can bring, in terms of ensuring public safety and the insurance and indemnification and the cross-waivers. All those things are available as part of the overall regulatory process. And NASA brings to the table its unique experience, in terms of human spaceflight and spaceflight operations, and we think, together, that can end up being a win-win for the government and for the industry.

Senator NELSON. In cargo operations, what you've done would apply. But, are there any new regulatory authorities that you believe the FAA will require, with regard to crew development activities, in going up to the Space Station?

Dr. NIELD. I would say that, given the guidance that Congress has provided so far, which is that—again, under the Commercial Space Launch Amendments Act of 2004, Congress clearly stated, "Space transportation is inherently risky," and we can't forget that.

We need to protect the public on the ground. Now, how can we minimize the risks as much as possible during these risky and experimental flights? I think we have a regulatory environment that works, right now, recognizing that NASA may well have specific mission requirements that it wishes to impose—for example, to ensure the safety of the International Space Station, or human-rating specific requirements—and they would be certainly free to do that within the contracts that they agree to with industry. So, I think there is a potential way ahead that would take advantage of the strengths of each of the organizations.

Senator NELSON. Well, since the FAA is involved in the safety of airplanes, does it have any business in getting into the question of human safety in spacecraft?

Dr. NIELD. Based on direction from Congress, yes, we already have that responsibility, and we look forward to working with the Congress and with the other stakeholders, including NASA, in improving our environment, going forward.

Senator NELSON. Well, I passed the first Commercial Space Act, back in the 1980s, and I never intended for the FAA to be getting into this.

Now, I know that NASA is not a regulatory agency, and therefore, needs to work with the FAA to establish regulations. But, I don't want to get this into a situation where we've just got extra layers of bureaucracy to go through just to get a crew up to the International Space Station.

General you're smiling.

General STAFFORD. Well, Mr. Chairman, when you talked about government crews to that—I think, in that—really, the only one that really has the expertise to write that is going to be NASA and what Colonel O'Connor has with his group, as far as government crews. If you talk about civilian crews going to some other thing that is nongovernment, that is—could be a completely different issue. But, I agree with you, sir. You don't want layers of bureaucracy. But, for government crews, I think it should be NASA, period.

Senator NELSON. Mr. Gass, could an EELV be integrated with a smaller crew exploration vehicle?

Mr. GASS. Yes.

Senator NELSON. Could you, for example, integrate it with one that had three astronauts instead of six?

Mr. GASS. Yes. We've looked at many configurations. You know, you—as we've talked before, United Launch Alliance is a merchant supplier, so we're working with many companies. But, we have done work with the Orion Program and some other different configurations of various sizes. Inside the EELV fleet, we have all sizes of rockets, as well. But, at the high end, we talk about an Orion or Orion Lite vehicle, and have that capability, have the launch infrastructure ready to go, so we can support that kind of crew vehicle, which is kind of—it's for—work for LEO, but it also goes LEO and beyond; it has that basic capability for future exploration.

The other side is true LEO vehicles, the vehicles that have been optimized for low-Earth orbit, and they would use the lower end of our launch family. So, at United Launch Alliance, we're prepared to support the wide range of options that are being considered. And

we're doing work with all of those systems right now, and using everything from our low-end Atlas rocket, a basic singlestick rocket, to the big Delta IV heavy—are options for all of those configurations.

Senator NELSON. If you were told, "Go," how long would it take you to do a CEV?

Mr. GASS. I think—working with the CEV team, I think we could have an unmanned test flight inside 3 years. And the reason I say that with some credibility, we're working on some of the most complex national security spacecraft that come with a whole lot of complexity of integrating spacecraft to launch vehicle. Working that depth of integration, assuming that the CEV—the Orion-type program is moving along and funded properly and it's making its progress, I think we could have that first flight in 3 years, using existing launch infrastructure. Full human flights would probably be in the 4-year timeframe, and we're looking at different launch pad options.

Senator NELSON. You could do unmanned in 3 years and then be ready to fly humans to the Space Station in 4 years.

Mr. GASS. Correct.

Senator NELSON. OK. Now, Ms. Shotwell says that she can do it in 3 years.

Mr. GASS. Name that tune.

Senator NELSON. What's that?

Mr. GASS. If we can play "Name that tune," but it's, again, that—you know, working with credibility of what are the interactions between the different contractors, NASA agencies—there are clearly options and—you know, we look at the spectrum of an all-NASA system to an all-commercial system; there's in-between. And I would look at—what I just referenced is kind of an in-between kind of solution; strong government involvement, a vehicle that is more extensible than just low-Earth orbit that gets to that added complexity. You go on the simpler side, to true commercial to LEO, it could probably be done more expeditiously.

Senator NELSON. And, Mr. Culbertson, you said that it would take a little longer than 3 years, if I recall what you said earlier.

Mr. CULBERTSON. Three to four years is what I said, sir, because, as was pointed out earlier, development programs typically take longer than originally estimated, and I'd like to set the expectations appropriately, right now, because we really don't know what the requirements we're going to be working to are, exactly. There's a lot of uncertainty, and exactly what—how that will impact our system, how much interaction we'll have to have with NASA and the FAA, and what will be required of the company to certify our system. And so, there's a minimum number, and there's a maximum number. That maximum number could go out as far as 5, under bad circumstances. But, I think 3 to 4 is a reasonable estimate that most of industry could probably subscribe to.

Senator NELSON. OK. If it were 5, that was the original schedule for the Ares I; it was going to be in 2016. So, any way we look at it, we're looking—5, 6 years relying on Russian spacecraft to get crews to the Space Station.

Mr. CULBERTSON. At least until 2015, yes, sir.

Senator NELSON. At least until 2015.

Mr. CULBERTSON. Depending on when you wave the green flag. You know——

Senator NELSON. That's correct.

Mr. CULBERTSON.—that all depends on the budget.

Senator NELSON. Let me ask Ms. Shotwell and Mr. Culbertson—we're going to try to make some decisions on our authorization and work with the appropriators on which way we're going. What assurances can we tell our folks that your timetables for supporting the Station won't slip?

Ms. SHOTWELL. Given where we are in the stage of development of both Falcon 9 and Dragon, we're very confident with the 3-year timetable that we've laid out. I don't know how to assure that, other than we are committed to doing it. We have the Falcon 9 vehicle at Launch Complex 40 at Cape Canaveral right now. It should be ready to fly within the next month or so. The Dragon spacecraft, the first Dragon spacecraft for NASA, will fly in July. And keep in mind that, again, Falcon 9 has been designed to accommodate a crew-rating certification, and the same with Dragon. So, we're not starting from scratch. You'd really have to look at the development timelines that we've had to date for Falcon 9 and Dragon, and add to that the 3 years that we're talking about now, moving forward. And then the timelines don't look ridiculous, by any stretch.

Mr. CULBERTSON. The timeline we're working on right now for COTS has slipped a few weeks and months, over the time that we've had the contract. But, not an unreasonable amount, given the complexity of the job and the late award of the contract to Orbital for the COTS demo mission. So, we've stayed pretty close to our original milestones, with a little bit of slip.

I'm not going to give you a timeline for commercial crew, at this point, because we don't honestly have one, because we don't know exactly what the requirements are going to be that we're going to have to meet. We're working on those things. It would be premature for me to make those kind of statements, at this point, until we see an RFP and we see the standards that Brian was talking about, and understand what that would require us to do. But, once we set a timeline, we will try to set it as realistically as possible.

Senator NELSON. I'd like to ask the three of you—that have the commercial carriers—I don't think that this scenario will occur, but you've got to have a business plan for it, if it did, and that is, what would happen if there were some emergency on board the ISS, and they had to vacate the ISS so that cargo and crew services by commercial providers was not necessary? What happens to your companies?

Mr. GASS. I'll——

Senator NELSON. Mr. Gass?

Mr. GASS. Thank you, Senator. First, I'll kind of reiterate what Mr. Peterson said. You know, when we deal with these kind of high-risk investment issues, there's an underlying market risk, there's technical risk, and there's operational risk. What you just described is really the market risk that—first off, Is the market of the U.S. Government buying services very secure? And then, What happens if something catastrophic happens for it to end suddenly?

That basically precludes why any rational investor would put in private capital into this market. There's got to be some other reason why we're doing it. So, unless the government program is structured in such a way that investment cost is covered, with either some sort of termination liability, it's going to be very difficult to attract true, rational investment capital.

Mr. CULBERTSON. Mr. Gass is correct, in—and in general, you would have to make sure that you have some kind of protection, if you were—particularly, investing billions, rather than what's currently being invested.

As far as our current cargo contract, if the Space Station were to cease to operate, then, yes, that would be a business impact to the company. Orbital is structured in such a way, and we're broad enough in our business base, that it wouldn't have a major impact on the company, but it would certainly be something that would change our plans over the next couple of years.

We're working, on a mission-by-mission basis, on a fixed-price basis; and what we have to order ahead of time, we order ahead of time; what we don't, we wait until we need it. And so, we just have to balance all of those impacts.

I do think that if something like that were to happen, we would certainly offer to work with the U.S. Government to come up with a solution to re-man the station, resupply it, and figure out if there is a way for the commercial world to help restore a laboratory like that. I think it's that important to the country that we ought to all work together to come up with solutions. It'll—it might be expensive, it might be difficult, depending on the problem, but I think it's something we ought to all have as a contingency plan.

Ms. SHOTWELL. The market for SpaceX Launch Services is quite broad, because we compete internationally, as well. So, there's no question that if we were to lose the cargo resupply contract that we have now, it would be a hit to our business case, but it would be, by no means, devastating. As I mentioned earlier in my testimony, we have 30—I believe we have 32 flights on our manifest right now, 24 of which are Falcon 9, and we're about ready to sign another 10 or so. So, it would be a hit, but, again, we don't go from something to zero. We still can provide Falcon 9 launch services for satellite providers, and we also have other customers outside the U.S. Government that's interested in Dragon.

Senator NELSON. Of your 30 flights, how many are COTS flights for cargo?

Ms. SHOTWELL. Three are COTS flights, 12 are CRS flights, and the remaining are satellite delivery flights. Actually, there was one commercial Dragon on the flight, as well—on the manifest, as well.

Senator NELSON. There's one what?

Ms. SHOTWELL. Commercial Dragon.

Senator NELSON. Ms. Shotwell, what assurances—well, we covered that.

Do you all have anything else? Do you have any more?

OK. I think we have gone through all of the questions that we want, at this point. Are there any concluding comments that any of you all would like to make?

General? I knew you'd have something to say.

General STAFFORD. Well, from my experience, going back to *Gemini,* sir, that everything has taken, always, longer than what was forecast, on every program; and in most of them, it's cost more money that was forecast. So—and I don't know—you could check with Mr. Peterson, I don't know if he's experienced anything any different, but that's been my experience for 40 years, sir.

Mr. PETERSON. If we are serious about the commercial cargo and commercial crew, as a matter of national policy, I would recommend to the Committee that you put, with the help of the appropriators, sufficient funds on the table to allow a program to proceed without hindrance from the funding process and the potential shortfalls in funding that stop progress and prevent—cause rework, and all those things that delay activities.

I also believe that you're going to want to look at, if it is truly going to be commercial, some form of protection for the investors. If you're going to get commercial money, you're going to have to have some basis to know that they're going to do so with at least, perhaps, recovery of their invested capital—they'll probably lose their opportunity cost of capital. I don't know if I'd pay them interest. But, I think it is wise to assume that this is going to be a difficult process, to raise capital, and we should take some steps to mitigate that risk.

Mr. GASS. Well, just to, maybe, build on the same thought. But, first, I think we shouldn't be—beat ourselves too much. There's been great successes, in our space industry, where we have been able to deliver on schedule, within cost, and continue to improve, over the generations. This is a risky business. When we talk commercial and have the U.S. Government being the main buyer, that is a little bit of an oxymoron of mixing different market areas. So, we need to be careful of what we're really trying to buy. I think the U.S. Government being the smart buyer, moving from a full indigenous, internal capability to start using commercial enterprise to help support that mission, is something that I think is very doable, but it needs to be in a measured approach, and we stand ready to support.

Senator NELSON. You all have been a very illuminating panel, and we thank you very much. We're plowing new ground here in a time of exceptional opportunity. So, I want to thank you for adding to the knowledge base today. You all are very kind to be here.

Again, I apologize for the interruptions of the votes, but that's the environment in which we live, here.

Thank you all for your testimony.

The meeting is adjourned.

[Whereupon, at 5:15 p.m., the hearing was adjourned.]

A P P E N D I X

PREPARED STATEMENT OF HON. JOHN D. ROCKEFELLER IV,
U.S. SENATOR FROM WEST VIRGINIA

Last month, the Obama Administration proposed a new path forward for NASA that refocuses the agency's overall direction. That new direction includes significant funds—$812 million in FY 2011 and $6 billion over 5 years—to stimulate the development of the commercial space market.

Congress is examining the budget closely, and as this Committee begins to move on NASA's reauthorization, this hearing will start to explore both the promise and the risk of relying on commercial companies for space access.

Investments in technology innovation always carry tremendous potential. We know space exploration has produced many technologies of great value to people's everyday lives.

Yet, exploration is still expensive and risky. It is clear that using the commercial market to bring down costs and allow NASA to focus on its greater mission could be an effective strategy.

Still, NASA and the administration have not yet provided key details about how this investment will be executed. To support a domestic commercial market, NASA will need to transition to a new way of doing business. New requirements and regulations will need to be developed in coordination with the FAA and implemented to ensure crew safety.

The space program is still at a critical juncture. With any new proposal or substantial investment we can never forget to ask that simple critically important question: does it work for our country—will it help our people?

I know today's witnesses can begin to help us answer that vital question. Thank you very much for your perspective and expertise.

PREPARED STATEMENT OF HON. DAVID VITTER, U.S. SENATOR FROM LOUISIANA

I want to thank the Chairman for scheduling this important hearing. NASA is at a critical stage in its history and I believe that, because of the Administration's proposed radical new direction for NASA, it is crucially important that we ascertain just what are the true current and near-future capabilities of commercial space companies to provide safe, reliable transport of U.S. astronauts to low earth orbit and the International Space Station. Given that the president's proposal would invest billions of taxpayer dollars in this endeavor and leave the United States without a government-owned launch and crew vehicle on which to rely, it is imperative that we get an accurate accounting of where these commercial companies are in their technological development, of just what the cost will be, what the timetable will be for delivery of these systems, and what the impact will be on our current NASA workforce.

I would like to welcome our panel of witnesses. I look forward to hearing your testimony and to you sharing your valuable experience and expertise on these subjects, and I thank all of you for taking the time to appear here before this committee today.

As everyone in this room should know by now, I have serious concerns and grave misgivings about the proposal to rely strictly on commercial providers for U.S. manned space flight. Indeed I have yet to see any convincing evidence that this proposal is viable, or that it will lead to anything other than the ruin of our proud space program, the loss of our role as the world's leader in space exploration, and the loss of tens of thousands of jobs at NASA facilities around the country.

Particularly in respect to the inevitable job loss at NASA facilities should we follow this path, I have yet to hear anything other than the vaguest assurances that "something" will be found for these highly-skilled and invaluable workers to do or that they'll find new work in the commercial space industry "somewhere," or that commercial providers "may" be looking to move some of their work into NASA facili-

ties. Neither I nor the thousands of NASA workers and their families now facing the prospect of losing their jobs because of this proposal can find much optimism or solace in such vagaries. This issue weighs on me heavily, and I am keenly interested in what our witnesses here have to say about this matter.

I am also deeply concerned that this proposal will only widen the "gap" in our manned space flight capability, leaving us to rely solely on Russia for space flight services for an indefinite period of time. This possibility is completely unacceptable to me, and, I am sure, to most Americans. We have worked hard and sacrificed much to achieve our role as the world's leader in space exploration, and I am deeply concerned that if we go this direction now, when so much about commercial spaceflight is uncertain and unproven, that we will inevitably cede that leadership role to Russia, China, and other nations with ambitions in space.

All of that is not to say, however, that I am utterly opposed to the idea of commercial space flight. I have no doubt that commercially-provided space flight to low earth orbit—both cargo and crew—is the future. However, I do not believe that future is now, and have yet to see any evidence to the contrary. To date, no commercial company has yet to even prove that it can reliably deliver cargo to the ISS. Given that, I firmly believe that it is both premature and irresponsible to entrust our entire manned space flight program to commercial providers at this time—subsidizing them with billions of taxpayer dollars in the process—and therefore imperative that we continue the development and then operation of a government-owned crew launch system built by our experienced and proven NASA work force. When commercial providers have proven themselves in flight and demonstrated that a viable and robust market exists for commercial spaceflight, then and only then do I believe it is logical to completely turn over manned space flight to low earth orbit to them.

That being said, I look forward to hearing all of your testimonies here today, and I hope that you will provide this committee with an accurate, reliable picture of where commercial spaceflight is in its development process, with reliable timetables for delivery and operation of both cargo and crew vehicles, with accurate estimates of cost, and with any ideas or considerations you may have for providing employment opportunities for our NASA workforce and the utilization of NASA facilities.

Thank you all again in advance for your testimony.