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NASA'S COMMERCIAL CREW DEVELOPMENT PROGRAM: ACCOMPLISHMENTS AND CHALLENGES

HEARING

BEFORE THE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

ONE HUNDRED TWELFTH CONGRESS

FIRST SESSION

WEDNESDAY, OCTOBER 26, 2011

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NASA'S COMMERCIAL CREW DEVELOPMENT PROGRAM: ACCOMPLISHMENTS AND CHALLENGES

WEDNESDAY, OCTOBER 26, 2011

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

The Committee met, pursuant to call, at 10:04 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Ralph Hall [Chairman of the Committee] presiding.

Ralph Hall, Texas
Chairman

Eddie Bernice Johnson, Texas
Ranking Member

U.S. House of Representatives
Committee on Science, Space, and Technology
Suite 2321 Rayburn House Office Building
Washington, DC 20515-6301
(202) 225-6371

NASA's Commercial Crew Development Program: Accomplishments and Challenges
Wednesday, October 26, 2011
10:00 a.m.-12:00 p.m.
2318 Rayburn House Office Building

Witnesses

First Panel

Mr. John Elbon
Vice President and General Manager for Space Exploration, The Boeing Company, Houston, TX

Mr. Steve Lindsey
Director of Space Exploration, Sierra Nevada Space Systems, Louisville, CO

Mr. Elon Musk
CEO and Chief Technology Officer, Space Exploration Technologies Corp., Hawthorne, CA

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The Hon. Paul Martin
Inspector General, National Aeronautics and Space Administration

Mr. William H. Gerstenmaier
Associate Administrator, Human Exploration and Operations Mission Directorate, National Aeronautics and Space Administration

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

NASA's Commercial Crew Development Program: Accomplishments and Challenges

Wednesday, October 26, 2011
10:00 a.m. - Noon
2318 Rayburn House Office Building

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Mr. William H. Gerstenmaier, Associate Administrator, Human Exploration and Operations Mission Directorate, National Aeronautics and Space Administration

Introduction

Last year with the rollout of the FY11 budget request, the Administration announced significant changes to NASA's human space-flight program, including its intention to cancel NASA's *Constellation* program, and instead put the agency on the path of relying on commercial launch companies to ferry astronauts to and from the International Space Station. Congress did not fully embrace the agency's full set of proposals, especially in the areas of heavy lift and a deep space exploration program, but with passage of the NASA Authorization Act of 2010 (PL 111-267), policy provisions in the bill (Title IV) authorized the agency to expand efforts to develop a commercial crew launch industry.

NASA's rationale for embarking on the commercial crew option was predicated on a report written by the "Review of U.S. Human Spaceflight Plans Committee" chaired by Norman R. Augustine. Published in October 2009, the report – *Seeking a Human Spaceflight Program Worthy of a Great*

[1] Blue Origin, based in Kent, WA, was invited but chose not to attend. They were awarded a $22 million Space Act Agreement grant under NASA's Commercial Crew Development Program.

Nation – included a number of findings and recommendations, and asserted that the *Constellation* program was 'unsustainable,' that to maintain a credible human spaceflight program NASA needed to spend an additional $3 billion annually, and that commercial industry was mature enough to take on the task of ferrying astronauts to and from low Earth orbit at a lower cost[2], although this path did have some risk.[3] The report also stated that "It is crucial to the success of the program that multiple providers be carried through to operational service."[4]
(http://www.nasa.gov/pdf/396093main_HSF_Cmte_FinalReport.pdf).

A key component of the commercial cargo and crew programs is the mixing of private and federal funds to pay for design, development, testing, and certification. Instead of a classic acquisition with NASA paying a contractor to design and build a space vehicle to its own specifications, under the commercial concept private industries will have to invest substantial amounts of their funds to build vehicles of their own designs. NASA will share in the cost of the development, and in the event the company's design proves successful, meets NASA's performance and safety requirements, and is selected by the agency in a final competition, NASA would 'buy' seats to ferry astronauts back and forth to the space station. Thus the commercial model allows NASA to leverage its own funds to acquire launch capabilities at a reduced cost, and it allows the commercial company to sell seats to non-NASA passengers.

NASA began commercialization efforts in 2006 with the Commercial Orbital Transportation Services (COTS) program to develop a commercial cargo capability. COTS was also viewed as an opportunity to test new contracting methods to incentivize industry. According to NASA the "*COTS approach is designed to lower barriers to entry for entrepreneurial space transportation companies*," and act as a *"catalyst for technology demonstrations where the potential high return on investment outweighs the associated financial risk."*[5]

Congress endorsed the cargo program. However, designing, testing, and demonstrating the cargo capability has proven more difficult than anticipated. The two companies now under contract for delivery services, SpaceX and Orbital, have missed their original COTS demonstration flights by a period of two years and one year, respectively. Crew transportation services impose significant new design and performance complexities that will likely result in greater uncertainty about meeting development schedules going forward.

On February 1, 2010, NASA initiated the first phase of its Commercial Crew Development program (CCDev1), awarding $50 million under Space Act Agreements (SAA) to five companies. On April 18,

---

[2] "Commercial services to deliver crew to low-Earth orbit are within reach. While this presents some risk, it could provide an earlier capability at lower initial and life-cycle costs than government could achieve." Augustine Report, page 72.

[3] "The Committee recognizes that the development of commercial services to transport crew come with significant programmatic risks. Among these are the development of this capability will distract current potential providers from the near-term goal of successfully developing commercial cargo capability. Second, the commercial community may fail to deliver a crew capability in mid-program, and the task would revert to NASA. This could be caused by either a technical failure or a business failure..." Augustine Report, page 71.

[4] Augustine Report, page 72.

[5] Commercial Crew and Cargo Briefing to Congress, 4 December 2007.

2011, second round awards (CCDev2) were announced, totaling $269.3 million to four companies.[6] Two companies that were not selected as part of CCDev2 later chose to participate through "unfunded" agreements.[7] This hearing will give both the funded and unfunded companies participating in CCDev2 and NASA an opportunity to describe their launch systems, accomplishments, and challenges confronting the Commercial Crew Program.

In the meantime, until a commercial crew launch system becomes operational in the planned 2017 timeframe, NASA will be reliant on Russia's Soyuz launch system to ferry astronauts to and from the ISS. NASA currently has a contract with the Russians to purchase Soyuz seats including all necessary training and preparation for launch, crew rescue and landing, and limited crew cargo delivery to and from the ISS through July 1, 2016. The current contract costs approximately $56 million per seat thru 2013, increasing to approximately $62.7 million in 2014 and 2015 to cover general inflation in Russia. In total, from FY2012 – FY2016, NASA expects to spend about $1.4 billion if it fully exercises all contracts.

Sec. 501 of the 2010 NASA Authorization Act directs NASA to support 'full and complete utilization of the ISS through at least 2020.' Under NASA's current schedule estimates, the Commercial Crew Program expects to have a commercial crew capability in place by early 2017. Agency plans call for two flights a year using commercial providers to rotate station crews; thus, NASA's demand for services will number about six or seven flights total. That projection could increase if ISS utilization is extended, or diminish if station is restricted to a crew size of less than six.

In the FY2012 budget request, NASA asked for $850 million for each of the years 2012 – 2016 for the Commercial Crew Program ($4.2 billion total). Last week senior NASA officials publicly stated that the agency requires its full request of $850 million in FY2012 if it's to meet a 2017 operational readiness date. However, the budget request did not provide meaningful detail at the project or activity level about how funds would be spent and the rationale for the amount requested, other than highlighting agency plans to begin the phase 3 (IDC) contract awards.[8]

Current State of Commercial Crew Funding

	PL 111-267 Authorization	FY12 PBR	FY12 House	FY12 Senate
Commercial Crew	$312M*	$850M	$312M	$500M

*NASA Initial FY11 Operating Plan dated 6/15/2011 - Commercial Crew Development funded at authorized levels.

[6] See Appendix A for a list of the CCDev2 companies.

[7] A third unfunded participant, Excalibur Almaz, Inc., signed a SAA on Oct. 17. However, no information was made available about their schedule and milestones at the time this charter was written.

[8] In a briefing earlier this month to subcommittee staff, charts provided by the agency stated: "NASA has been told consistently, by a broad range of potential providers, that private sector partners expect to be able to achieve a capability of providing commercial spaceflight services to the ISS within 3-5 years from initial development start...NASA's FY2012 budget request of $850M for commercial crew would provide that initial start in FY2012 for development of commercial crew transportation systems which would enable services to ISS to be possible in the 2016 timeframe." The briefing charts also stated that the House FY2012 CJS appropriations mark for commercial crew services - $312 million, the amount authorized in the 2010 NASA Authorization Act – would cause the agency to reconsider its acquisition approach.

Questions and Overarching Issues

- What are the major accomplishments to date by industry on efforts to develop a commercial crew launch capability? What are the remaining major technical challenges that must be addressed?
- From industry's perspective, what are the biggest programmatic challenges with NASA's Commercial Crew Program regarding (1) the agency's procurement strategy and (2) its approach to insight and oversight?
- What are the industry's assumptions about the size and vitality of the commercial market (non-US government) for launching astronauts to low Earth orbit?
- What are the likely sources of non-Government passengers that are willing and able to afford the high cost of a trip to space?
- What are NASA's plans to acquire one or more operational commercial crew systems for ferrying astronauts to and from the International Space Station?
- What does NASA consider to be the biggest challenges confronting commercial crew developers as they attempt to develop and demonstrate their launch vehicle and crew systems?
- Have clear lines of responsibility and accountability been established to ensure safe and successful design, development and operation of human systems?
- What requirements and processes is NASA adopting to maintain the highest level of crew safety, including design and reliability standards for a launch abort system? What steps is NASA taking to coordinate requirements and regulations with the Federal Aviation Administration to ensure compatibility?
- What level of federal investment does NASA require to ensure that at least two commercial providers will be certified and sufficiently funded?

Background

Commercial Crew Development Program Acquisition Strategy

NASA initiated the Commercial Crew Development (CCDev) Program during FY2010, and divided it into four phases: CCDev1 (funded in FY2010 and completed April 2011) awarded grants to five companies; CCDev2, now underway with four funded and two unfunded participants (final milestones scheduled to be completed between May - July 2012); the third phase called the Integrated Design Contract (IDC) – to be awarded in July 2012 with a final integrated system design due April 2014; and the fourth phase known as Development/Test/ Evaluation/Certification (DTEC) that will, at its completion, provide a fully operational and certified commercial launch system. NASA's goal is to have at least two companies complete all four phases by early FY2017.

The CCDev1 and CCDev2 funded recipients received their awards under Space Act Agreements (SAA), which is another name for 'Other Transaction Authority'. Funded SAAs are much less onerous than traditional federal acquisitions, allowing NASA the flexibility to negotiate individual contracts with unique milestones, schedules, and payments for each grant recipient. There are no penalties for failure to deliver under an SAA, other than the recipient doesn't get paid for milestones that are missed. Just as importantly, accounting and audit standards are not required under an SAA. Companies prefer to perform under an SAA rather than following the usual FAR-based (Federal Acquisition Regulations) rules, which are expensive and cumbersome but are designed to ensure that companies meet rigorous accounting and performance standards.

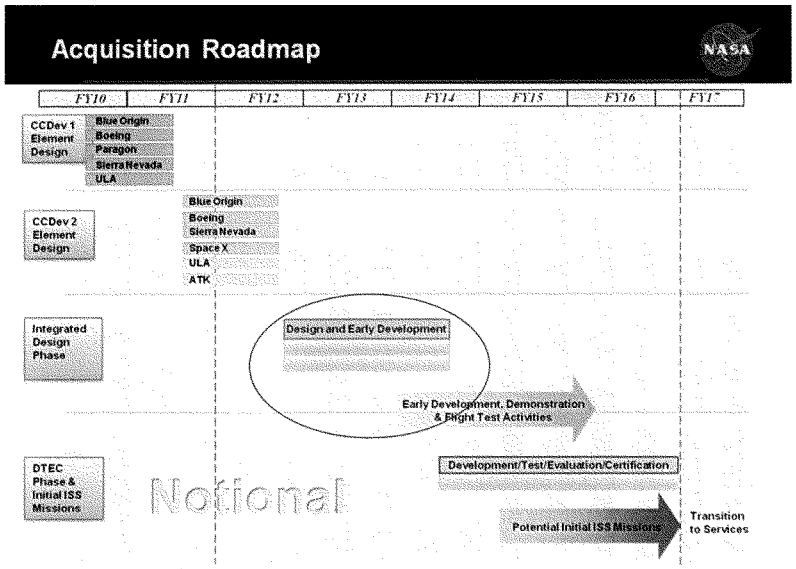
SAAs can be used for research and development activities, and for the acquisition of technologies in support of agency missions such as seeding development of commercial cargo and crew launch by private industry. However, SAAs cannot be used to acquire actual services; those must be purchased using the FAR. NASA intends to use the FAR with SAA-like exceptions for the Integrated Design Contract and the Development/Test/Evaluation/Certifications phases of the Commercial Crew Program.

Although the government is funding much of the development, private companies will ultimately own and operate the designs and systems. Instead of the government defining what is needed, the private companies will propose specific designs, development activities and schedules in meeting NASA's objectives. There is no requirement for the government to receive certified cost or pricing information. The government will not retain the Intellectual Property and data rights. Additionally, as a cost saving measure, NASA will delegate to the companies the responsibility to ensure that lower-level suppliers provide components meeting specified performance requirements. Previously, NASA would take on this oversight role, but by actually specifying parts and processes to be used. In this way NASA will no longer control *how* the government's requirements are met, and instead give that responsibility to the private companies.

Rather than require companies to comply with detailed NASA standards, NASA now intends to use 'embedded insight teams' in an attempt to determine whether the private company's designs, components, and systems "meet the intent" of NASA's standards and practices.

The chart that follows (taken from a NASA presentation) reflects the agency's strategy and schedule going forward. According to NASA the schedule shown assumes funding of $850 million per year for the program; for FY2012 the House CJS mark is $312 million, the Senate mark is $500 million.

As reflected in the chart, NASA is currently in the middle of the CCDev2 phase, with the IDC phase due to begin in July 2012. One issue that bears highlighting in this plan is that the agency intends to require interested applicants – presumably including some or all of the CCDev2 participants – to submit final IDC applications before they've completed their CCDev2 milestones. As a result, companies may be unable to fully characterize their achievements prior to NASA awarding IDC contracts. Based on current schedules, CCDev2 milestones for two funded companies won't be completed until the end of July 2012. The other two CCDev2 funded companies won't complete their milestones until early May 2012, after the April application deadline has expired. Consequently, there is a concern that those companies could be disadvantaged in the subsequent competition.



Note too that the number of horizontal bars for the IDC phase is less than the number for CCDev2 participants, an indication of NASA's plan to down-select (fund fewer companies in later phases). And going to the DTEC (final) phase, it appears that no more than two applicants are contemplated to be funded.

Report by the NASA Office of Inspector General

On June 30, 2011, NASA's OIG issued an audit report entitled: "NASA's Challenges Certifying and Acquiring Commercial Crew Transportation Services."[9] As the title suggests, the report highlights five programmatic challenges that must be addressed if NASA is to successfully develop a commercial space industry that could meet the agency's needs to low Earth orbit. They are:

- modifying NASA's existing safety and human-rating requirements for commercially developed systems;
- selecting the acquisition strategy for commercial crew transportation services;
- establishing the appropriate insight/oversight model for commercial partner vehicle development;
- relying on an emerging industry and uncertain market conditions to achieve cost savings; and
- managing the relationship between commercial partners, the Federal Aviation Administration (FAA), and NASA.

[9] (http://oig.nasa.gov/audits/reports/FY11/IG-11-022.pdf).

The IG report cautioned that assumptions about the size and growth of non-Government commercial markets are largely unknown.[10] As an example, the report pointed to the failed commercialization attempt by the Department of Defense Evolved Expendable Launch Vehicle (EELV) program. When expected commercial demand for EELV vehicles did not materialize, the costs grew 77 percent in 1 year. The two commercial providers formed a single entity in an effort to control costs, which eliminated competition.

The report concluded by stating:

> "While we are not making specific recommendations for corrective action, we believe NASA must pay particular attention to the challenges highlighted in this report. Specifically, NASA should:
>
> • clearly articulate to its commercial partners as soon as possible all requirements for commercially developed systems and the processes NASA will use for certifying such systems;
>
> • maintain robust communication with the emerging commercial spaceflight industry to ensure that Agency contracting mechanisms include the appropriate balance between insight and oversight that will provide NASA with sufficient information to assess and certify commercial partners' systems while providing companies the flexibility to be innovative;
>
> • clearly articulate how it will mitigate potential conflicts of interest that may arise as a result of analysis that could provide an unfair competitive advantage to a NASA partner; and
>
> • expand coordination with the FAA to avoid the potentially serious business impacts that would result if commercial companies were required to operate in an environment that included inconsistent sets of standards for NASA certification and FAA licensing of the same vehicle."

Commercial Crew Market Studies and Demand Projections

Two government-sponsored reports have been issued in the last 15 months that speak to the size and vitality of commercial (non-US government) demand for seats on commercial crew launch systems. The Federal Aviation Administration, through its office of Commercial Space Transportation, issued "A Report of the Commercial Human Spaceflight Workshop" that was held August 4 – 6, 2010. (http://www.faa.gov/about/office_org/headquarters_offices/ast/media/Report%20of%20the%20Commercial%20Human%20Spaceflight%20Workshop.pdf)

[10] See appendix B.

Section 403 of the 2010 NASA Authorization Act required NASA to do "...an assessment, conducted in coordination with the Federal Aviation Administration's Office of Commercial Space Transportation ... of the potential non-Government market for commercially-develop crew and cargo transportation systems and capabilities..." NASA's study, "Commercial Market Assessment for Crew and Cargo Systems" was issued April 27, 2011. (http://www.nasa.gov/pdf/543572main_Section%20403(b)%20Commercial%20Market%20Assessment%20Report%20Final.pdf)

Of the two studies, the FAA report is clearly more sober – if not pessimistic – in its assessment about the size of the non-government markets, and the business case confronting companies seeking to serve them. Two paragraphs excerpted from the Executive Summary follow:

> "The workshop discussions demonstrated that no traditional business case exists that would allow companies to support near term orbital human transportation as fully commercial activities, utilizing company investment and servicing commercial customers, at a price point that can reasonably be expected to generate true commercial sales. This is true because there is insufficient market, including both government and non-government customers, to repay the steep investment required. However, if government interests are considered broadly (including stimulating economic growth and ensuring the health of the vital space industrial base) there may be a non-traditional "business case" that serves both national needs for access to low Earth orbit and the needs of the nascent commercial industry.
>
> Despite some optimistic claims to the contrary, there is little evidence of a commercial human orbital market at the current price point of orbital space flight. Although a few individuals have purchased commercial flights on Russian spacecraft, their ticket price only had to cover the marginal cost of a fully developed system supported by a stable government business base. No such system or government business base exists in the US, and when amortization of development costs and fully-loaded operational costs in a new start program are accounted for, the per seat cost soars to a price point which makes a commercial market vanishingly small. However, the workshop identified several approaches and considerations that may bring the price point down to a level where a commercial market can develop."

The FAA report does suggest, however, that "While a traditional business case (privately funded development with broad commercial and government customer base) could not be found, we believe that given the right assumptions a sufficient case can be built to justify NASA transitioning to the use of commercial human space transportation."[11]

The report concluded: "While appropriate, the move to transition human space transportation to the private sector is a high risk undertaking. If made, its risk means the government must recognize the full set of consequences and incorporate appropriate risk management in its planning and execution. It also means that the industry's growth can be accelerated substantially by the wise use of government policies and acquisition strategies."[12]

NASA's report, "Commercial Market Assessment for Crew and Cargo Systems", looks at both crew and cargo, but without taking into account NASA ISS crew and cargo needs. The report breaks down its projections into four categories; National Interests (nations without an indigenous human spaceflight capability that have sent astronauts to orbit using another nation's launch system); Space

[11] Report of the Commercial Human Spaceflight Workshop. FAA. Page 3.
[12] Ibid. Page 18.

Tourism; Applied Research and Technology Development; and Other Markets (e.g., satellite servicing).

For purposes of this hearing – focusing on non-government crew – it provides ten year projections using estimates for a 'Lower End of Range' and a corresponding 'Upper End of Range' number of seats. The associated cargo estimate reflects the amount of food, water and other consumables required to sustain the astronauts, relying on ISS astronaut consumption rates at 10.3 pounds per day per crew member.

NASA Non-Government Estimates (Over ten years)

	Lower Range	Upper Range	Amt. of Cargo
National Interests	36	186-216	6,180 – 28,430 lbs.
Space Tourists	8	143	990 – 17,700 lbs.

According to the NASA report, the variability of the National Interests estimate largely depends on whether one private company, Bigelow Aerospace, successfully launches an inflatable "commercial" space station as an alternative destination to ISS. With respect to Space Tourism, estimate variability is determined by the availability of crew transportation systems for non-professional astronauts, cost, and the current lack of a destination besides the ISS. One question for Congress to consider is the role of the ISS as a tourist destination.

The NASA report concludes by stating:

> "If successful, NASA's Commercial Crew Program will provide assured access to the ISS. It will end the gap in the US-provided human access to space and ensure we do not cede the US leadership role in space. It will also allow NASA to concentrate its limited resources on exploration beyond LEO, enabling NASA to go further faster in the exploration of the solar system. It benefits US private industry by strengthening the US industrial base, enhancing our capabilities, and capturing market share of a new high technology industry. In addition, it benefits the Nation with more jobs, economic growth, and opportunities for human spaceflight for a variety of people (e.g., astronauts, international partner personnel, scientists, spaceflight participants) for a variety of reasons (e.g., science, research, ISS operations, tourism).
>
> For these reasons, it is important that the Congress support NASA's commercial cargo and crew efforts. Delays in the availability of commercial spaceflight capabilities negatively affect the markets described in this report and degrade the business case for commercial providers. Catalyzed by a successful Commercial Crew Program, a stable commercial non-Government market is likely to emerge. Without this catalyst, prospects for such a market emerging are considerably lessened. New potential suppliers are poised to try, and now is the time to open this new vista for American industry."

The first panel of funded and unfunded CCDev2 companies will have an opportunity to describe their proposed plans for launch and crew systems, and the challenges they face. The second panel consisting of NASA's Inspector General and the Associate Administrator for Human Exploration and Operations will discuss the issues confronting the agency as it moves forward with the unique acquisition strategy to develop commercial crew vehicles as well as stimulating and supporting the market as the anchor tenant.

Appendix A

On April 18, 2011, NASA awarded approximately $270 million to four commercial companies to continue development of commercial rockets and spacecraft capable of safely flying astronauts into orbit and to the International Space Station. The award was the second phase of the agency's Commercial Crew Development effort, known as CCDev2, proposals selected were:

- Blue Origin: $22 million. The company is working on a space vehicle design development for their biconic "New Shepard" spacecraft, designed to take off and land vertically.

  Blue Origin was founded in 2000 by Jeff Bezos, the CEO of Amazon.com, in Kent, WA and is privately funded. Originally focused on suborbital flights, the company has also begun development of an orbital spacecraft with funding from NASA's CCDev awards.

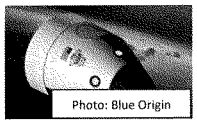


Photo: Blue Origin

- Sierra Nevada Corp.: $80 million. Sierra Nevada is designing a lifting body crew capsule called "Dream Chaser."

  Sierra Nevada Corp's Space Exploration Systems (SES) product line is developing the "Dream Chaser" spacecraft, which it acquired in the 2008 purchase of SpaceDev. Work on the vehicle is based in Louisville, CO with additional offices in seven Houston, TX. Corporate wide, Sierra Nevada Corp has business units located at 29 different locations.

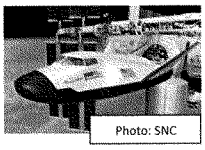


Photo: SNC

- Space Exploration Technologies (SpaceX): $75 million. SpaceX plans to use the award to develop an escape system for a crewed version of its Dragon capsule, an uncrewed version of which has already flown.

  SpaceX was founded in 2002 by Elon Musk, who also co-founded PayPal, Tesla Motors and serves as Chairman of SolarCity, with the goal of developing low cost access to space.

  SpaceX headquarters is located in Hawthorne, CA where it manufactures the Falcon 9 rocket and the Dragon capsule.

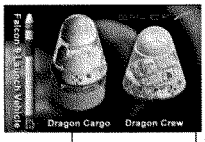


Photo: SpaceX

Appendix A

- The Boeing Company: $92.3 million. The Boeing Company will continue development of the CST-100 crew capsule, including maturation of the design and integration of the capsule with a launch vehicle.

  The CST-100 development work is a project under the Space Exploration unit of the Network and Space Systems business line primarily conducted by offices in Houston, TX.

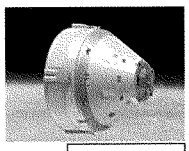


Photo: Boeing

NASA has also awarded two unfunded Space Act Agreements that has allowed the agency to collaborate with two additional rocket providers on the CCDEV2 program.

- United Launch Alliance (ULA): for the CCDev2 program, provide data on the Atlas V rocket, a flight-proven expendable launch vehicle used by NASA and the Department of Defense for critical space missions.
  NASA will share its human spaceflight experience with ULA to advance crew transportation system capabilities and the draft human certification requirements. ULA will provide NASA feedback about those requirements, including providing input on the technical feasibility and cost effectiveness of NASA's proposed certification approach.

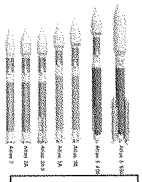


Photo: ULA

- Alliant Techsystems (ATK): for the CCDev2 program, collaborate on the development of the Liberty Launch System.

  NASA and ATK will review and discuss Liberty system requirements; safety and certification plans; computational models of rocket stage performance; and avionics architecture designs. The agreement outlines key milestones including an Initial System Design review, during which ATK will present to NASA officials the Liberty systems level requirements, preliminary design, and certification process development.

  The Liberty rocket is similar to the canceled Ares 1 rocket that was under development at NASA within the Constellation program. The Ares 1 rocket used an ATK 5-segment solid rocket booster motor as a first stage. The Liberty rocket would use the same 5-segment rocket motor for a first stage and use the main liquid engine from the Ariane-5 rocket built by the French company Arianespace as the upper stage.

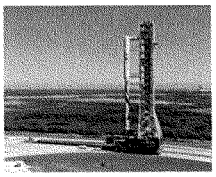


Photo: ATK

Appendix B

Excerpts from
"NASA's Challenges Certifying and Acquiring Commercial Crew Transportation Services"
NASA Office of the Inspector General
Report No. IG-11-022, June 30, 2011

Lessons Learned from the Evolved Expendable Launch Vehicle Program.
Historically, past predictions of the demand for commercial launch vehicles have been overly optimistic. Moreover, competition in a demand-constrained environment can have unintended consequences. For example, Lockheed Martin and the Boeing Company were rival launch vehicle service providers in the Department of Defense's Evolved Expendable Launch Vehicle (EELV) Program. When expected demand for EELV launch vehicles did not materialize, estimated prices for launch services increased 77 percent in 1 year. In an effort to provide more cost-effective and reliable launch vehicles in the face of limited demand for their services, the companies combined their EELV operations in December 2006 to form United Launch Alliance, LLC. The formation of United Launch Alliance eliminated competition and forced the Government to rely on a single provider of launch services to meet its intermediate- and heavy-class launch vehicle requirements. Consequently, near-term limited demand can stifle competition – a cornerstone of NASA's commercial crew services goals. (Page 19.)

Impacts of Near-Term Limited Demand.
Because of the near-term limited demand for commercial crew transportation services, it is likely that NASA's commercial partners will attempt to augment their business with commercial and Government satellite launches. For example, SpaceX is developing rockets that can transport satellites to orbit, including a rocket to compete with United Launch Alliance in the EELV market. However, FAA predictions for satellite launch vehicle demand through 2019 remain flat or slightly decline, although the FAA points out that opportunities for growth in the overall launch vehicle market could occur if a viable, commercial human spaceflight market emerges. (Page 19.)

Appendix C

"Report of the Commercial Human Spaceflight Workshop"
FAA Office of Commercial Space Transportation
Workshop Held August 4 – 6, 2010

Key Findings

- While a traditional business case (privately funded development with broad commercial and government customer base) could not be found, we believe that given the right assumptions a sufficient case can be built to justify NASA transitioning to the use of commercial human space transportation.

- The workshop participants expressed a general confidence that a commercial human space flight market will develop over time. They had considerably less confidence in the near term viability of human space flight as a purely commercial enterprise. The more experienced space flight companies unanimously agreed that they cannot see a viable business case for their companies unless specific government actions are taken to reduce the level of corporate investment required, limit financial liability, and guarantee a stable market. They cited consistently over-estimated markets and under-estimated technical challenges in past space flight programs. One entrepreneurial company with limited space flight experience felt optimistic that it could lower its costs to a point where significant government investment would not be required.

- The first principles financial considerations of a satisfactory business case are defined by straightforward mathematics (see appendix C). Analyses performed in the course of this work show that the currently defined market, including both commercial and government customers, is simply too small and speculative to give confidence that privately funded efforts can achieve an acceptable rate of return on the investment. Absent significant government investment in system development or the emergence of a non-government customer significantly larger than NASA, the required price significantly exceeds the cost of purchasing seats from Russia.

- The enormous uncertainties in market size and sustainability further undermine the business case for investment. The current absence of NASA requirements or declared intentions to fly humans in LEO post 2020 is both critical and easily remedied. An assured market limited to ten missions, potentially split between multiple providers, does not provide a sufficient sales volume to repay the significant investment required.

- Industry also has significant concerns about liability, the availability of funding for system development, and the challenge of repaying that investment in a reasonable period at fair market rates of return.

Appendix C

- The commercial aerospace industry possesses the engineering skills and manufacturing capabilities to deliver high quality launch vehicles and spacecraft. However, none of these companies has experience conducting human space flight operations. Thus NASA will want to remain closely involved in operations of complex human missions conducted on its behalf.

- As a result of these issues, industry and the panel agree that if policy makers decide that a transition to commercial launch services is in the national interest, the government must take aggressive measures to support the development of the industry, such as the following:

  a. Act as the anchor tenant customer for the foreseeable future, including guaranteeing a market greater than five years of ISS support.

  b. Invest in system and/or infrastructure development to limit capital require-ments and shorten payback periods. Several companies required that the government fund at least part of the development of the human system as a condition of their participation.

  c. Offer or facilitate limitations on liability.

  d. Provide mature, stable requirements, including human rating requirements, as soon as possible.

  e. Ensure that NASA and the FAA agree on a coherent set of requirements and regulations that enable fielded systems to serve both government and non-government customers.

  f. Insulate commercial providers from financial penalties associated with schedule impacts that may arise from conservative decisions required to operate safely.

The panel believes that moving human space flight to a commercial business model is appropriate and timely, but possible only under three pivotal assumptions:

- That there is a compelling national interest in the government continuing to fly humans to low earth orbit beyond 2020 and that such interest is codified in policy and budget planning.

- That there is a compelling national interest in investing in commercial human space capabilities, even at a cost significantly greater than Soyuz rates initially, or alternatively, with the government bearing a significant portion of the system development costs.

- That the government ensures that NASA requirements and FAA regulations are written to guarantee that flight systems developed for government missions are also acceptable and affordable for commercial customers.

Chairman HALL. The Committee on Science, Space, and Technology will come to order, and I say good morning to everyone.

Mrs. Johnson, before we get started with the meeting, I will go ahead and ask the witnesses to indulge us just for a few minutes to take care of some Committee business here. It is my understanding Ms. Johnson as the Ranking Member of the Full Committee has some housekeeping she would like the Committee to undertake regarding the Democrat Caucus Subcommittee Ranking Member assignments and rosters. The proposed modified roster is in front of each of you here. I am not sure if some of their members want to switch parties, or what this is about, but we will yield to you as much time as you would like to have.

Ms. JOHNSON. Thank you very much, Mr. Chairman. We just want to announce that we are taking applications for party switches to this side.

But we do have a couple of Subcommittee vacancies to fill on the Democratic side, and so pursuant to the direction of the Democratic Caucus of the Committee, I move that the following Subcommittee assignments be made: Ms. Edwards of Maryland to serve as Ranking Member of the Subcommittee on Technology and Innovation; that Mr. Tonko of New York replace Ms. Edwards as Ranking Member of the Subcommittee on Investigations and Oversight; and that Mr. Clarke of Michigan be assigned to serve on the Subcommittee on Space and Aeronautics. And that ends our report and request. Thank you.

Chairman HALL. All right. Without objection, it is so ordered.

I now ask unanimous consent that the Committee adopt the revised roster in front of them reflecting these appointments as outlined by Ranking Member Johnson. Hearing no objection, the revised roster is adopted.

Moving on, I would like to welcome everyone to today's hearing, "NASA's Commercial Crew Development Program: Accomplishments and Challenges." That covers a long area there looking back and looking forward, and in front of you are packets containing the written testimony, biographies and Truth in Testimony disclosures for today's witnesses, and today's hearing will include two panels, and I recognize myself for five minutes for an opening statement.

I say to all, good morning, and thank you. I know it takes valuable time to travel here and to travel back and to prepare yourselves for this, and we write legislation based on things we hear from people like you because you know more about what you are doing than we know about what you are doing, and we want to be sure that we represent the greatest good for the greatest number as we legislate. So I say good morning to all of you, to NASA's commercial crew group, and I would like to thank our witnesses for taking time from their very busy schedules to be with us, and we will try to keep everybody to the five minutes that we have allocated. I realize considerable effort goes into the drafting and writing of your statements, and I want you to know that your testimony, wisdom and experience is going to be invaluable to help us through the months ahead on issues that are related to NASA and its Commercial Crew Program.

I would like to note for the Members of the Committee that one company, Blue Origin, has received $14.9 million in federal funds

under this program but declined to testify today. I don't really know why they did. Fourteen point nine million, I would think I would want to come here and brag about it a little or explain something. But they are not here and they will have to explain that to the rest of the Committee when they want to.

Today's hearing is going to provide aerospace companies and NASA an opportunity to testify about progress being made toward the goal of establishing a purely commercial capability to fly humans to and from low Earth orbit, with an initial emphasis on ferrying NASA astronauts to the International Space Station.

Some have described the Commercial Crew Program as a variation on the way NASA has traditionally managed our human spaceflight program, implying that not much will change in the relationship between the agency and aerospace companies in the acquisition and operation of space vehicles. I find this characterization to be a gross oversimplification that doesn't fairly represent the degree of changes between the space launch industry and NASA, nor does it do anything to highlight the uncertainties of the business model going forward.

I am not opposed to the new approach, but in the time remaining I want to focus my remarks on the business case, as that is an area that I would like to see discussed at greater length.

If indeed industry can perform safely and profitably, and at substantially less cost, then I will be the first to congratulate them and NASA. My hesitance, though, is based on the very thin evidence provided to date by NASA that this new business model is well understood and that it can succeed. I have yet to be convinced that there is a sufficient commercial market that will sustain multiple private, for-profit commercial crew companies through the duration of America's commitment to the International Space Station. I hope so. NASA seemingly takes the position of "build it and they will come," and by starting these companies first, business will soon follow. From my perspective, the business case is not very compelling, at least for those companies intending on using NASA as an anchor customer. Assuming two commercial companies will be certified by the end of 2016, at two flights a year for four years based on NASA's projections, government may need only eight flights. That is four flights per company, probably at a rate of one a year. The number may grow if the International Space Station is extended, but there is no guarantee. Four flights to recover some significant portion of sunk investment, coupled with the goal to price the service at a rate that doesn't dwarf the cost now charged by Russia, suggests to me a perilous business proposition.

I think that NASA owes Congress and the laudable companies that are before us today a much more thorough assessment of the situation ahead. These companies have invested millions of dollars and Congress has committed millions more. It is time for NASA to deliver credible plans and analysis so that we can move forward with more confidence.

What I do not want to see happen is putting government in the position of stepping in to salvage one or more failing companies in order to preserve a national capability. Many of us are well aware of the debacle that confronted the Air Force with its EELV program, and this Committee is not prepared to let NASA repeat that

mistake. To paraphrase my friend and former Chairman of this Committee, Bart Gordon, I don't want to find ourselves at some future time throwing additional sums in this program because the commercial launch companies are "too important to fail."

For all my seeming skepticism, I am willing to be convinced that I am wrong, and I hope I am wrong. I want the private markets to relieve NASA of the cost and burden of building a new launch system for low Earth orbit. But as I said a minute ago, NASA must do more to address these important questions, and it is our role as the Committee of jurisdiction to ensure that whatever path we ultimately take, government's investment will be well understood and well spent.

In a time of constrained budgets, we have to first protect our presence in space and keep the faith with the American people and our foreign partners. Logically, we cannot expend vast sums of money today going to Mars when our people can't go to the grocery store. But we have to keep the dream alive by moving forward as we are able. That is why it is vitally important that we spend our limited NASA dollars wisely.

I want to offer thanks again to our witnesses. I greatly admire the achievements of you and your companies. It is undeniable that aerospace has directly contributed to this country's greatness and our preeminence in space, and all of us must work to ensure you have the missions and resources to continue that good work in the years ahead.

[The prepared statement of Mr. Hall follows:]

PREPARED STATEMENT OF CHAIRMAN RALPH HALL

Good morning and welcome to today's hearing entitled "NASA's Commercial Crew Development Program: Accomplishments and Challenges." I'd like to thank our many witnesses for taking time from their busy schedules to appear before our Committee. I realize considerable effort goes into the drafting and writing of statements, and I want you to know that your testimony, wisdom, and experience will be of invaluable help to our Committee and Congress as we deliberate in the months ahead on issues related to NASA and its Commercial Crew Program. I would like to note for the Members of the Committee that one company, Blue Origin, has received $14.9 million in Federal funds under this program but declined to testify today-and, I have declined to subpoena them.

Today's hearing will provide aerospace companies and NASA an opportunity to testify about progress being made toward the goal of establishing a purely commercial capability to fly humans to and from low Earth orbit, with an initial emphasis on ferrying NASA astronauts to the International Space Station.

Some have described the Commercial Crew Program as a variation on the way NASA has traditionally managed our human space flight program, implying that not much will change in the relationship between the agency and aerospace companies in the acquisition and operation of space vehicles. I find this characterization to be a gross over-simplification that doesn't fairly represent the degree of changes between the space launch industry and NASA, nor does it do anything to highlight the uncertainties of the business model going forward.

I am not opposed to this new approach, but in the time remaining I want to focus my remarks on the business case, as that is an area that I would like to see discussed at greater length. If indeed industry can perform safely and profitably, and at substantially less cost, then I will be the first to congratulate them and NASA. My hesitance though, is based on the very thin evidence provided to date by NASA that this new business model is well understood and that it can succeed. I have yet to be convinced that there is a sufficient commercial market that will sustain multiple private, for-profit commercial crew companies through the duration of America's commitment to the International Space Station. NASA seemingly takes the position of 'build it and they will come'; that by starting these companies first, business will soon follow.

Some say the business case is not very compelling, at least for those companies intending on using NASA as an anchor customer. Assuming two commercial companies will be certified by the end of 2016, at two flights a year for four years based on NASA's projections, government may need only eight flights. That's four flights per company, probably at a rate of one a year. The number may grow if ISS is extended, but there's no guarantee. Four flights to recover some significant portion of sunk investment, coupled with the goal to price the service at a rate that doesn't dwarf the cost now charged by Russia, suggests to me a perilous business proposition. I think that NASA owes Congress and the laudable companies that are before us today a much more thorough assessment of the situation ahead. These companies have invested millions of dollars and Congress has committed millions more—it is time for NASA to deliver credible plans and analysis so that we can move forward with more confidence.

What I do not want to see happen is putting government in the position of stepping in to salvage one or several failing companies in order to preserve a national capability. Many of us are well aware of the debacle that confronted the Air Force with its EELV program, and this committee is not prepared to let NASA repeat that mistake. To paraphrase my friend and former Chairman of this Committee, Bart Gordon, I don't want to find ourselves at some future time throwing additional sums in this program because the commercial launch companies are 'too important to fail.'

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I want to offer thanks again to our witnesses. I greatly admire the achievements of you and your companies. It is undeniable that aerospace has directly contributed to this country's greatness and our preeminence in space, and all of us must work to ensure you have the missions and resources to continue that good work in the years ahead.

Chairman HALL. The Chair now recognizes Ranking Member Mrs. Johnson for her five minutes, which could be 10. You have the time that you choose to use, Ms. Johnson.

Ms. JOHNSON. Thank you very much, Mr. Hall, and good morning. I would like to join Chairman Hall in welcoming all of our witnesses this morning. The companies appearing before us are doing exciting work, and they are a great example of American industry's capacity for innovation. Today's hearing is a unique opportunity to hear from each of them, or each of you, about their accomplishments and aspirations and the challenges they face, and I look forward to the testimony.

However, I want to be clear from the outset. I cannot let my enthusiasm for entrepreneurial innovation override my responsibility as a Member of Congress to take a clearheaded look at the issues associated with NASA's commercial crew proposal. And it is clear that there are many issues that need to be addressed and questions that NASA still has not answered more than a year and a half after the initiative was first announced. In my opening remarks, I will focus on two of the issues that need our attention: priorities and risk.

Let me first say a few words about the issue of priorities. Given the cuts that are being made and contemplated to NASA's and our other federal agencies' important missions as well as to essential services for the most vulnerable in our society, I have got to be con-

vinced that the benefits of NASA's commercial crew proposal outweigh the costs before I can be comfortable in supporting it.

What are the benefits? As NASA and others have described them, they are several-fold. First, Commercial Crew would reduce, but not eliminate, dependence on Russia for International Space Station-related goods and services. NASA estimates that the cost to the U.S. government to purchase Russian crew transportation and rescue services would be about $450 million a year from 2016 to 2020, or a total of about $1.8 billion for those four years.

Second, NASA and others have argued that the commercial crew initiative will help create a new commercial crew space transportation industry with a wide range of public and private customers, thus lowering costs and allowing NASA to focus on deep space exploration.

What are the costs of the initiative? Last week, NASA's Deputy Administrator was quoted as saying that "we have an analysis that says we believe we would require $6 billion over five years" to develop the commercial crew systems. I have to take the Deputy Administrator at her word, as NASA still has not provided Congress with the basis for its commercial crew budget requests since the initiative was first announced almost two years ago, though I find it unsettling that the $6 billion estimate is almost $2 billion more than the amount actually book-kept for Commercial Crew in the NASA five-year budget plan that was submitted to Congress in February of this year.

Now, that $6 billion is just to develop the systems. Perhaps we will hear otherwise today, but all of the information provided by NASA to date indicates that it believes that the U.S. commercial crew systems will be competitive with the Russian Soyuz in price per seat but not significantly cheaper. So, at this point it looks like NASA will still be paying roughly the same amount to commercial crew providers through 2020 that it would be to the Russians.

So as a result, I and other Members will have to decide whether it is worth paying a $6 billion premium in taxpayer dollars in order to make a domestic ISS commercial crew capability available to replace the Russian system for a four-year period, assuming the U.S. commercial crew systems are certified operational by 2016. Now I would rather not pay money to the Russians either, but I will find it very hard to justify to my constituents spending an extra $6 billion to transport our astronauts to the ISS for a limited amount of time unless I can also credibly argue that doing so will open up a broad new competitive market in commercial crew transportation for American industry. Unfortunately, based on the information provided by NASA and others to date, I can't make that argument.

The only potential non-NASA markets of any significance identified by NASA for the foreseeable future are a small number of super-wealthy individuals seeking adventure trips, provided the price is right, and a small number of non-U.S. astronauts, provided their countries are willing to pay for their trips. I will be frank: I don't think that the prospect of spending $6 billion in taxpayer dollars to enable either super-rich tourists or non-U.S. astronauts to fly into orbit is going to be seen as a worthwhile priority by very many of my constituents in the current fiscal environment, and I

have a feeling that many of my fellow Members will also find that to be the case.

Let me close by saying a few words about risk. I am not talking about risk to our astronauts, because I have to believe that NASA will not put any of our astronauts on a commercial system until it is convinced that NASA's safety standards have been met. Instead, what I am talking about is the risk to the U.S. government and the American taxpayer. That risk takes several forms. For example, there is the risk that the cost and schedule assumptions behind NASA's plans will not prove valid. As it is, even if the President's commercial crew budget request is approved in total, NASA's latest acquisition roadmap projections indicate that any contract for commercial crew transportation services to the ISS won't start until 2017, which is almost two years later than originally estimated. NASA cautions that even that date could slip further depending on funding and the rate of progress made by the companies. Thus the likelihood that the commercial systems will be able to meet a significant portion of ISS crew transportation needs prior to 2020 is shrinking, and that is a risk to the viability of NASA's proposal that I find worrisome.

That risk is also one reason we mandated in the NASA Authorization Act of 2010 that NASA needs to put a credible government backup capacity—capability in place as soon as possible to support the ISS operations if needed.

And finally, if a public-private partnership is to protect both the interests of the taxpayers and the companies, cost risks need to be shared. However, NASA officials indicate that, on average, 9 out of every 10 dollars spent to develop the commercial crew systems will be taxpayer money. In addition, unless we hear otherwise today, the would-be commercial providers have indicated that they expect the government to indemnify them in the event of an accident. That may or may not be good public policy, but unless there is sufficient private insurance coverage available to them to cover at least part of their potential accident liability, the reality is that the government may well be on the hook for the entire amount, at risk—or risk losing the company that it is relying on, we are relying on to get NASA's crews to and from the ISS.

In conclusion, Mr. Chairman, none of the issues I have raised here should take away from the good work that the companies represented at this hearing are doing. I applaud their efforts and wish them well. I certainly plan to keep an open mind regarding NASA's commercial crew initiative, and I hope that NASA will provide all of the information and analyses Congress will need to properly evaluate this initiative.

However, as Members of Congress, we must be vigilant stewards of the taxpayers' dollars, and we cannot let either enthusiasm nor hope blind us to that responsibility as we assess NASA's proposals.

I thank you, and I yield back.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF RANKING MEMBER EDDIE BERNICE JOHNSON

Good morning. I would like to join Chairman Hall in welcoming all of our witnesses to this morning's hearing. The companies appearing before us are doing exciting work, and they are a great example of American industry's capacity for innovation. Today's hearing is a unique opportunity to hear from each of them about

their accomplishments, their aspirations, and the challenges they face. I look forward to their testimony.

However, I want to be clear from the outset. I cannot let my enthusiasm for entrepreneurial innovation override my responsibility as a Member of Congress to take a clearheaded look at the issues associated with NASA's commercial crew proposal.

And it's clear that there are many issues that need to be addressed and questions that NASA still has not answered more than a year and a half after the initiative was first announced. In my opening remarks, I will focus on two of the issues that need our attention: priorities and risk.

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I have to take the Deputy Administrator at her word, as NASA still has not provided Congress with the basis for its commercial crew budget requests since the initiative was first announced almost two years ago—though I find it unsettling that the $6 billion estimate is almost $2 billion more than the amount actually bookkept for commercial crew in the NASA five-year budget plan that was submitted to Congress in February of this year.

Now that $6 billion is just to develop the systems. Perhaps we will hear otherwise today, but all of the information provided by NASA to date indicates that it believes that the U.S. commercial crew systems will be "competitive" with the Russian Soyuz in price per seat but not significantly cheaper. So, at this point it looks like NASA will still be paying roughly the same amount to commercial crew providers through 2020 that it would be to the Russians.

As a result, I and other Members will have to decide whether it is worth paying a $6 billion premium in taxpayer dollars in order to have a domestic ISS commercial crew capability available to replace the Russian system for a four-year period—assuming the U.S. commercial crew systems are certified operational by 2016. Now I would rather not pay money to the Russians either, but I will find it very hard to justify to my constituents spending an extra $6 billion to transport our astronauts to the ISS for a limited amount of time unless I can also credibly argue that doing so will open up a broad new competitive market in commercial crew transportation for American industry.

Unfortunately, based on the information provided by NASA and others to date, I can't make that argument.

The only potential non-NASA markets of any significance identified by NASA for the foreseeable future are a small number of super-wealthy individuals seeking adventure trips—provided the price is right, and a small number of non-U.S. astronauts—provided their countries are willing to pay for their trips.

I will be frank—I don't think that the prospect of spending six billion taxpayer dollars to enable either super-rich tourists or non-U.S. astronauts to fly into orbit is going to be seen as a worthwhile priority by very many of my constituents in the current fiscal environment, and I have a feeling that many of my fellow Members will also find that to be the case.

Let me close by saying a few words about risk. I'm not talking about risk to our astronauts, because I have to believe that NASA will not put any of our astronauts on a commercial system until it is convinced that NASA's safety standards have been met.

Instead, what I am talking about is the risk to the U.S. government and the American taxpayer. That risk takes several forms. For example, there is the risk that the cost and schedule assumptions behind NASA's plans will not prove valid. As it is, even if the President's commercial crew budget request is approved in total,

NASA's latest acquisition roadmap projections indicate that any contract for commercial crew transportation services to the ISS won't start until 2017, which is almost two years later than originally estimated.

NASA cautions that even that date could slip further depending on funding and the rate of progress made by the companies. Thus the likelihood that the commercial systems will be able to meet a significant portion of ISS crew transportation needs prior to 2020 is shrinking, and that's a risk to the viability of NASA's proposal that I find worrisome.

That risk is also one reason we mandated in the NASA Authorization Act of 2010 that NASA needs to put a credible government backup capability in place as soon as possible to support ISS operations if needed.

Finally, if a public-private partnership is to protect both the interests of the taxpayers and the companies, cost risk needs to be shared. However, NASA officials indicate that, on average, nine out of every ten dollars spent to develop the commercial crew systems will be taxpayer dollars. In addition, unless we hear otherwise today, the would-be commercial providers have indicated that they expect the government to indemnify them in the event of an accident.

That may or may not be good public policy, but unless there is sufficient private insurance coverage available to them to cover at least part of their potential accident liability, the reality is that the government may well be on the hook for the entire amount—or risk losing the company that it is relying on to get NASA's crews to and from the ISS.

In conclusion, Mr. Chairman, none of the issues I have raised here should take away from the good work that the companies represented at this hearing are doing. I applaud their efforts and wish them well. I certainly plan to keep an open mind regarding NASA's commercial crew initiative, and I hope that NASA will provide all of the information and analyses Congress will need to properly evaluate that initiative.However, as Members of Congress, we must be vigilant stewards of the taxpayers' dollars, and we cannot let either enthusiasm or hope blind us to that responsibility as we assess NASA's proposals.Thank you, and I yield back the balance of my time.

Chairman HALL. I thank the gentlelady for yielding back, and I thank you for a statement well done and I thank you as my neighbor in Texas.

If there are Members who want to submit additional separate opening statements, your statements will be added to the record at this point.

Chairman HALL. And I say to the witnesses and those who are important to this transaction, don't be dismayed by the empty chairs because we are at a critical time in this Congress and the world knows it and we all know it, and you as business leaders know it. Most of these men and women who are not here have other committee assignments and they are attending those, but all of this is of record. They will have it. It will be read and it will be here for people 200 years from now to read what this Committee said and what questions this group asked. So I will ask you to indulge with it.

At this time I would like to introduce, first, our panel of witnesses. Our first witness is Mr. John Elbon, Vice President and General Manager for Space Exploration at the Boeing Company. Previously, Mr. Elbon led Boeing's effort as a Prime Integration Contractor for the International Space Station. He has been the Boeing Program Manager for several NASA programs including Constellation and the checkout assembling and payload processing services contract at Kennedy Space Center, and we thank you, sir, for coming.

Our second witness is Steve Lindsey, the Director of Space Exploration at Sierra Nevada Space Systems. Mr. Lindsey came to Sierra Nevada this year after a distinguished 24-year career in the United States Air Force. As a NASA astronaut, he has flown five

shuttle missions, his last two flights as commander including STS–133 that flew earlier this year, and we certainly welcome you.

Our third witness is Mr. Elon Musk, Chief Executive Officer and Chief Technology Officer of Space Exploration Technologies, also known as SpaceX. Mr. Musk has many accomplishments. He is also the CEO and Product Architect of the electric car company Tesla Motors and the Nonexecutive Chairman of Solar City. Previously, Mr. Musk cofounded PayPal. We are very delighted to have you here. And because your Congressman has been very proud of your accomplishments, I am going to leave my last 2 minutes for him to say a few kind words about you. He has paid me good money to let him do this.

Mr. ROHRABACHER. Well, there is a lot of good words to be said about each and every one of our panelists today. All of you are people that I admire. You are in keeping with the American tradition of enterprise and technology, perhaps going all the way back to the clipper ships when people wanted to do business and designed ships and sailed off to distant shores, and we had the best ships of any country in the world, but today you all reflect those type of values.

Elon Musk, who I am going to say a few good words about now, Elon is a native South African who is now a proud American, and as you can see, as the Chairman just noted, he is involved in the development of electric cars as well as been involved in PayPal, which has enabled all of us to go into debt over the Internet.

Chairman HALL. Your time is almost up.

Mr. ROHRABACHER. So, let me just note that we are watching all of your accomplishments and especially you, Mr. Musk. Thank you for the 1,500 employees that you represent and everyone on this panel represents people who are employed and people who are getting something done by furthering America's tradition of enterprise and technology. Thank you very much.

Chairman HALL. Thank you, and Mr. Flores is at another committee hearing at this time. He wanted to be here to help with the introduction.

Our fourth witness on this first panel is Mr. Charlie Precourt, Vice President of Launch Systems Group of Alliant TechSystems, also known as ATK. Prior to joining ATK, Mr. Precourt also had a very distinguished 23-year career with the United States Air Force as an F–15 pilot and was a commander as a NASA astronaut, having flown on four shuttle missions including two as mission commander, and we are really delighted to have you here.

Our final witness on the first panel is Dr. George Sowers, Vice President in Business Development and Advanced Programs for United Launch Alliance. Dr. Sowers has a 30-year history working with America's most successful launch vehicles beginning with the Titan program and now with the Atlas V and Delta IV rockets. Welcome, Dr. Sowers.

As our witnesses need to know, spoken testimony is limited to five minutes, and after all the witness have spoken, Members of the Committee will have five minutes each to ask questions. We will try to stay with that five minutes if we can, but for the sacrifices you have made and for the input that you surely have and for the importance you are to this Committee, to this Congress and

to this Nation, if you go over five minutes, nothing is going to happen. We don't have a hook or anything, but we do want you to fully explain your presence here and your hopes and desires and your history and your future.

I recognize our first witness on the first panel, Mr. John Elbon of Boeing, to present his testimony.

STATEMENT OF MR. JOHN ELBON, VICE PRESIDENT AND GENERAL MANAGER FOR SPACE EXPLORATION, THE BOEING COMPANY, HOUSTON, TEXAS

Mr. ELBON. Good morning, Chairman Hall, Ranking Member Johnson, Members of the Committee. On behalf of the Boeing Company, I wish to convey my deepest gratitude for your continued support of human spaceflight. Your efforts have enabled a safe flyout of the space shuttle, completion of the International Space Station, and established a path forward for human exploration of space. Without your Committee's support, none of these achievements would have been possible. It is an honor to be a participant with this distinguished panel to elaborate on Boeing's development status to support reducing the gap in U.S. crewed access to the International Space Station.

Mr. Chairman, if it is okay, I have got a video I would like to show to begin with.

Chairman HALL. Without objection. We want to see it.

[Video playback.]

Mr. ELBON. There are three cornerstones of NASA's path forward for human spaceflight: utilization of the International Space Station, commercial crew for transportation to low Earth orbit and development of a capability for human exploration beyond low Earth orbit. By providing affordable crew transportation to the International Space Station, commercial crew will increase utilization of this on-orbit laboratory and free up funding and resources for NASA to focus on exploration beyond low Earth orbit. Because of this relationship, commercial crew should not be viewed as a competitor with deep space exploration programs but instead as a complementary program that contributes to achieving NASA's overall objectives.

In selecting a design for commercial crew, Boeing adopted three overarching principles. We would focus on transporting crew to low Earth orbiting platforms only so the vehicle capabilities could be kept as simple as possible. We would use as much off-the-shelf proven technology as possible in order to reduce the development risk and improve cost and schedule certainty, and our design would be as uncomplicated as practical to improve reliability and safety and to enable low operations cost. To date in our program, we have completed several significant design milestones and development tests.

Looking forward, prior to the completion of the second phase of commercial crew development in June of next year, we will mature the design of the complete integrated system, which includes the spacecraft, launch vehicle and ground systems through a preliminary design review, perform a parachute drop test from a helicopter ending with a touchdown on deployed airbags, integrate the emergency monitoring system of the Atlas V with the avionics of

the Crew Space Transportation system, CST–100, to demonstrate the required data communication in the event of a launch abort, and test-fire a new, lighter-weight version of the abort engine.

Assuming we are selected by NASA for the next procurement phases and that adequate funding is available and we complete our critical design review, the 90 percent point in the design process by the spring of 2013 and perform an ascent test later that year. We also are planning on flying three flight tests, which will culminate with the launch of two Boeing test pilots in 2015, leading to the capability to fly to the International Space Station by late 2015.

Human spaceflight is challenging and any program to develop a capability to transport humans in space must address these challenges. We have been transporting humans into earth orbit in capsules for nearly 50 years using design and technologies that are proven. We have reduced the technical challenges of the program to manageable levels.

There are two significant challenges that remain from Boeing's perspective, and they are programmatic in nature. The first is stable funding. If we are to achieve an operational capability by 2015, adequate funding levels must be provided over the next four years.

The second is addressing liability risk associated with the potential for accidents that result in damage to property or in death or injury to crew members or passengers. Although the likelihood of these occurrences is extremely low, the losses would be tragic and the potential monetary consequences could be high. With limited performance history, it will be difficult for industry to insure against these monetary losses at reasonable rates. As such, in order to close the business case, it will be necessary for NASA, the FAA and Congress to work together to provide indemnification and liability limitations.

With regards to the size of the potential market, it is clear that there is a commercial market for transportation to low Earth orbit. The depth of these markets is uncertain, though, and a responsible business case cannot be closed on the commercial business alone. Our business case assumes only NASA-purchased transportation to the International Space Station and treats revenue from private spaceflight participants and commercial transportation to Bigelow Space Complex is upside.

The commercial crew market would not be as attractive as it is if NASA were the only potential customer, but at the same time to ensure a successful venture, we must be certain we can have a viable business based on NASA flights alone. This is important from the government's perspective as well. It shouldn't be necessary for the government to gamble on the development of a commercial market in order to ensure a viable business will be in place to meet its needs for transportation to the International Space Station.

In closing, commercial-provided transportation to low Earth orbit is the right solution for enabling a complete and robust portfolio of NASA programs in science and human spaceflight. The risks in flying spacecraft to low Earth orbit are well understood. We have been completing successful low Earth orbit missions since John Glenn's historic flight in 1962. It is time to leverage the efficiencies of a different model for the relationship between NASA and con-

tractors for the part of space exploration where the risk levels warrant it. Commercial transportation to low Earth orbit supports lower cost utilization of the International Space Station and makes additional funding available for human exploration beyond low Earth orbit.

Thank you.

[The prepared statement of Mr. Elbon follows:]

PREPARED STATEMENT OF MR. JOHN ELBON, VICE PRESIDENT AND GENERAL MANAGER FOR SPACE EXPLORATION, THE BOEING COMPANY, HOUSTON, TX

Good morning, Chairman Hall, Ranking Member Johnson and members of the committee. On behalf of the Boeing Company, I wish to convey my deepest gratitude for your continued support of human spaceflight. Your efforts have enabled a safe fly-out of the Space Shuttle, completion of the International Space Station, and established a path forward for the future of human space exploration. Without your committees' support none of these achievements would have been possible. It is an honor to be a participant with this distinguished panel to elaborate Boeing's development status to support reducing the gap in U.S. crewed access to the International Space Station.

Programmatic Purpose for Commercial Crew

There are 3 cornerstones of NASA's path forward for human space flight: Utilization of the International Space Station, Commercial Crew for transportation to low Earth orbit, and development of a capability for human exploration beyond low Earth orbit. By providing affordable crew transportation to the International Space Station, Commercial Crew will increase utilization of this on-orbit laboratory and free up funding and resources for NASA to focus on exploration beyond low Earth orbit. Because of this relationship, Commercial Crew should not be viewed as a competitor with deep space exploration programs, but instead as a complementary program that contributes to achieving NASA's overall objectives.

Our Design Solution

In selecting a design solution for Commercial Crew, Boeing adopted 3 overarching principles: (1) we would focus on transporting crew to low Earth orbiting platforms only so the vehicle capabilities could be kept as simple as possible; (2) we would use as much "off-the-shelf", proven technology as possible in order to reduce development risk and improve cost and schedule certainty; and (3) our design would be as uncomplicated as practical to improve reliability and safety and to enable low operations costs. The solution we reached, based on these criteria, was an Apollo shaped capsule launched into orbit on the proven, dependable Atlas V. The Atlas family of rockets has a history of 98 consecutive successful launches and the Atlas V itself has a string of 27 consecutive successful launches. To compliment this reliability, our spacecraft includes a robust abort system that can carry the crew to safety in the unlikely event there is a problem with the launch vehicle during all phases of ascent. The capsule re-enters using an ablative heat shield and parachutes to a landing on a lake bed, cushioned by airbags. These features, in combination, lead to a very reliable system with a minimum of components that need to function properly for crew survivability. The use of existing systems and low complexity also results in low development risk ensuring the government that Boeing will be able to complete the development and testing of the system and that a return will be received on the taxpayer's investment. Finally, this

design will lead to a system with reasonable operating costs that will enable a U.S. solution that is competitive with current per seat prices for Russian Soyuz transportation.

Current Progress

To date on our program we have completed several significant design milestones and development tests. During the first phase of the Commercial Crew Development procurement, we completed a System Requirements Review, a Subsystem Definition review and Initial Safety Reviews. Also during the first phase, we completed development testing that included: Drop tests to prove operations of the airbags; Fabrication of pressurized structure using a new innovative technique that requires no welds and significantly reduces cost; Development of a simulator that demonstrates the capability to automatically dock with the International Space Station; Test firing of a development version of the abort engine; and completion of wind tunnel tests to characterize the aerodynamic loads during the critical abort phase.

Future Milestones

Looking forward, prior to completion of the second phase of Commercial Crew Development in June of next year, we will: Mature the design of the complete, integrated system, which includes the spacecraft, launch vehicle, and ground systems, through a Preliminary Design Review; Perform a parachute drop test from a helicopter ending with a touchdown on deployed airbags; Integrate the Emergency Monitoring System of the Atlas V with the avionics of Crew Space Transportation (CST)-100 to demonstrate the required data communication in the event of a launch abort; and test fire a new, lighter weight version of the abort engine. Assuming we are selected by NASA for the next procurement phases and that adequate funding is available, we will complete our Critical Design Review, the 90% point in the design process, by the spring of 2013 and perform an ascent abort test later that year. We also plan on flying three flight tests, which will culminate with the launch of 2 Boeing test pilots in 2015, leading to the capability to fly crew to the International Space Station by late 2015.

Programmatic Challenges

Human space flight is challenging and any program to develop a capability to transport humans in space must address these challenges. However, we have been transporting humans into earth orbit in capsules for nearly 50 years and by selecting a design and technologies that are proven, we have reduced the technical challenges of the program to manageable levels. There are two significant challenges that remain from Boeing's perspective and they are programmatic in nature. The first is stable funding. If we are to achieve an operational capability by 2015, adequate funding levels

must be provided over the next 4 years. The second is addressing liability risk associated with the potential for accidents that result damage to property or in death or injury to a crew member or passenger. Although the likelihood of these occurrences is extremely low, the losses would be tragic and the potential monetary consequences could be very high. With limited performance history, it will be difficult for industry to insure against these monetary losses at reasonable rates. As such, in order to close a business case, it will be necessary for NASA, the FAA and Congress to work together to provide indemnification and liability limitations.

Procurement Approach

There are two key attributes that should result from the Commercial Crew procurement approach in order to enable success. The first is creation of an operating environment that supports decision velocity. Because the risks and challenges of transportation to low Earth orbit are relatively well understood, as compared to more complicated missions carrying humans beyond the vicinity of earth, it is possible to safely design and operate a system in an environment where more decision authority is retained by the contractor. This reduces the required coordination and expedites the decision making process, leading to lower costs. The second attribute is that the contractor should retain intellectual property rights. This is necessary to encourage investment in establishing a commercial market beyond transportation of NASA funded passengers to the International Space Station. Boeing believes that both these attributes can be achieved using a FAR based contract. Furthermore, whether required by the procurement approach or not, we will use the same design processes and design standards we use for all development programs, including commercial programs such as commercial satellites and commercial airplanes. Processes like design reviews, safety reviews, documented manufacturing and operations procedures, configuration management, parts traceability and failure modes and effects analysis are used on all Boeing programs, government and commercial, because we have proven to ourselves, over time, that they are necessary to execute a successful program leading to a reliable design and safe operations.

Insight/Oversight

NASA has defined an environment for insight and oversight that we think will work well in the Commercial Crew environment. To achieve insight NASA will embed personnel as part of the development teams with access to development data so the government remains cognizant of design decisions and program status without the need for specially generated documents, reports or reviews. NASA oversight, which is the process through which NASA elects to direct changes in our design in order to meet top level human certification requirements, is limited to major design reviews, and reserved for those situations where it is deemed necessary to ensure crew safety and mission

success. Our experience during the first two phases of Commercial Crew Development has validated this approach. NASA personnel are included in our engineering reviews and program status meetings and they have participated in a manner that adds significant value through offering input to design discussions based on experience and concerns from past programs, but supporting the design decisions we make during the process. Oversight has not been a part of these early phases but through our design reviews we have received the opinions of NASA program leadership and we've iterated our design based on this so that only a very small number of design disconnects of any consequence remain. These will be discussed during our preliminary design review this March, and assuming we are selected to continue, will be resolved during the early parts of the next program phase.

Size and Vitality of the Commercial Market

With regards to size of the potential market, it is clear there is a commercial market for transportation to low Earth orbit. Proof of this can be found in the fact that 7 private space flight participants have paid for flight on Russian spacecraft to the International Space Station, and that Bigelow Aerospace has signed Memorandums of agreement with at least 6 countries that are interested in leasing space on the Bigelow Space Complex. The depth of these markets is uncertain though and a responsible business case cannot be closed on the commercial business alone. Our business case assumes only NASA purchased transportation to the International Space Station and treats revenue from private space flight participants and commercial transportation to Bigelow's space complex as upside. We have teamed with Space adventures, the company that brokered seats on Russian flights to the International Space Station, and with Bigelow Aerospace to ensure the system we are developing will meet their needs and to allow them to strengthen their offerings with the promise of safe and reliable transportation. The commercial crew market would not be as attractive if NASA were the only potential customer, but at the same time to ensure a successful venture, we must be certain we can have a viable business based on NASA flights alone. This is important from the government's perspective as well. It shouldn't be necessary for the government to gamble on the development of a commercial market in order to ensure a viable business will be in place to meet its needs for transportation to the International Space Station.

Closing

In closing, commercially provided transportation to low Earth orbit is the right solution for enabling a complete and robust portfolio of NASA programs in science and human space flight. The risks in flying spacecraft to low earth orbit are well understood. We've been completing successful low Earth orbit missions since John Glenn's historic flight in 1962. It's time to leverage the efficiencies of a different model

for the relationship between NASA and the contractors for the part of space exploration where the risk levels warrant it. Commercial transportation to low Earth orbit supports lower cost utilization of the International Space Station and makes additional funding available for human exploration beyond low Earth orbit.

Chairman HALL. I thank you. And once again, I will stress the importance of your offerings here and your service here. Heretofore back in September, we had Neil Armstrong, Gene Cernan and General Tom Stafford here all day. We kept them from early one morning until late at night, and anyone that says Neil Armstrong is not generous with his time or won't sign things for people, he did all day that day for us. That was very important, and Buzz Aldrin would be here today but he had a schedule problem, but he has been before this Committee a lot of times. So we value you. You all are very, very important to the future of NASA and help us work out the problem that we are faced with.

I now recognize Steve Lindsey to present his testimony, and thank you, John.

STATEMENT OF MR. STEVEN LINDSEY, DIRECTOR OF SPACE EXPLORATION, SIERRA NEVADA SPACE SYSTEMS, LOUISVILLE, COLORADO

Colonel LINDSEY. Thank you, Chairman Hall, Ranking Member Johnson and Members of the Committee for this opportunity to present Sierra Nevada's perspective on the Commercial Crew Program. Mr. Chairman, I have submitted a complete written statement that I would ask to be made part of the record.

I have only recently joined Sierra Nevada after serving for 24 years in the United States Air Force and 16 years in NASA, where I had the opportunity to fly on five space shuttle missions including commanding the final flight of Discovery this past February. What I would like to address this morning is who Sierra Nevada is and what we are doing as part of NASA's Commercial Crew Development Program. Sierra Nevada Corporation is a proven systems integrator, electronic systems and space systems provider with a reputation for rapid, innovative and agile technology solutions. We employ a highly talented staff of over 2,200 people, mostly engineers, scientists or technical personnel serving in six business areas across 20 states. Our strong financial track record and stable leadership structure are key elements in the successful yearly execution of hundreds of government aerospace contracts.

We are currently in our sixth year of the development of a human-rated lifting body spaceflight, and you can see the model here in front of me, called the Dream Chaser. The Heritage Dream Chaser design evolved from the NASA Langley Research Center's HL–20 spaceflight, which was originally designed as a lifeboat for the International Space Station. Langley performed more than 1,200 wind tunnel tests and performed thousands of piloted simulations in its decade-long investment refining their design. Sierra Nevada started with Langley's ten years of research and has invested an additional six years of capital, engineering, time and effort to develop a very sophisticated, reusable space plane that can satisfy NASA's low Earth orbit needs.

Sierra Nevada has assembled a world-class team of spaceflight-experienced partners to execute the Dream Chaser program including Boeing, United Launch Alliance, Aerojet and nine other U.S. companies. In addition, we have formed a unique industry-to-government partnership where we are funding seven NASA centers to provide expert assistance in designing and developing our

spaceflight. This superb team of experienced space companies and NASA centers employing aerospace workers across 13 states and growing allows us to rapidly develop our space system to provide a cost-effective and safe way to transport people to and from low Earth orbit.

Sierra Nevada's Dream Chaser program has been a part of NASA's Commercial Crew Program for the past four years. During CCDev1, we completed all technical and performance milestones on time and under budget, going well beyond the original contract and completing several additional unfunded milestones. We have completed the first four milestones of CCDev2 on time and on budget with the fifth to be completed tomorrow.

While every human-rated spaceflight in our Nation's history has in fact been built by a commercial company, there are some subtle differences between today's program and previous ones. Under the current program, the contractual mechanisms are the Space Act agreement, a fixed-price, pay-for-performance, milestone-based program. If we don't stay on schedule or meet our milestones, then we aren't paid. Companies are expected to contribute financially to the program and in fact Sierra Nevada has invested heavily in the Dream Chaser. This contracting mechanism is a cost-effective way for the government to retire technology development risk in mature and integrated design. In the next phase of the program, Sierra Nevada understands the government's need for greater oversight and looks forward to working with NASA under a tailored FAR-based contract.

The interaction between NASA and Sierra Nevada has evolved into a very unique partnership. NASA provides us spacecraft requirements which we have to meet or NASA simply won't contract for our services. To accomplish both the oversight and insight function, NASA has embedded a partner integration team of spaceflight experts directly into our company to provide a true inside view of our day-to-day operations. They participate in every aspect of our program, providing complete government insight into our design, development and testing. This approach is very effective, requiring less oversight due to the extraordinary level of insight.

Mr. Chairman, to conclude my remarks, I would like to talk a little bit about safety. While at NASA, I had the privilege to serve as Chief of the Astronaut Office for over three years overseeing the final servicing mission of the Hubble and the completion of the International Space Station. As Chief, my number one responsibility was the safety of my crews, and under my watch, we successfully executed 14 space shuttle missions and 10 space station missions, each time bringing our crews home safely. I made the difficult decision just a few months ago to leave 30-plus years of government service to come to Sierra Nevada. Why? Because I believe that access to space is vital to our national interests and I want to do everything in my power to get our Nation back into low Earth orbit as soon as possible. Let me assure all of you that under my watch, we will never, ever sacrifice safety for any reason. With our industry partners and NASA's guidance, we will do the job right. The space station is waiting and the clock is ticking. I strongly encourage this Committee and the Congress to fully support and fund NASA's Commercial Crew Program.

Thank you, Mr. Chairman, for the opportunity to share my views this morning.

[The prepared statement of Colonel Lindsey follows:]

PREPARED STATEMENT OF MR. STEVE LINDSEY, DIRECTOR OF SPACE EXPLORATION, SIERRA NEVADA SPACE SYSTEMS, LOUISVILLE, CO

Thank you, Chairman Hall, Ranking Member Johnson and Members of the Committee for this opportunity to present Sierra Nevada's perspective on the Commercial Crew Program.

Sierra Nevada Corporation (SNC)

Before addressing the questions you asked in your invitation letter directly, I'd like to provide you with a brief description of Sierra Nevada Corporation to indirectly answer how the depth and breadth of our company provide us with the capabilities necessary to develop a human-rated spacecraft for our Nation. Sierra Nevada Corporation (SNC) is a proven systems integrator, electronic systems and space systems provider with a reputation for rapid, innovative, and agile technology solutions. As a 100% U.S., privately held, woman-owned and operated business, SNC has been under the current ownership since 1993. It employs a highly talented staff of over 2,200 people, mostly engineers, scientists, or technical personnel. Our seven business areas have operations in 20 states. SNC has a very solid financial foundation and an uninterrupted profitable growth history with no long-term debt. SNC's strong financial track record and stable leadership structure are a key element in the successful yearly execution of hundreds of government contracts. SNC holds one of the highest possible Dunn & Bradstreet rating scores.

Sierra Nevada Corporation is currently in our sixth year of development of a human-rated spacecraft called the Dream Chaser Space System. The SNC team has invested a substantial amount of capital, engineering, time and effort to develop the technologies that support our Dream Chaser spacecraft. These technologies and expertise include hybrid propulsion systems, complex composite structures, airframe design, spacecraft components, adapter rings, navigation and control, life support, and integrated system design and testing capabilities. This previous work and our continuing NASA partnership will significantly lower development time and risk, and will help to ensure program success.

SNC has also assembled a world-class team of spaceflight experienced partners to execute the Dream Chaser Space System program. Boeing Experimental Systems Group has great expertise in lifting body spacecraft including analysis, avionics, Guidance, Navigation, and Control software, and flight control. Their recent X–37 spacecraft experience fits perfectly with our Dream Chaser development and risk reduction activities. United Launch Alliance (ULA) has been on our team for more than five years. jointly collaborating on an integrated launch vehicle that rapidly brings a safe, reliable, and cost-effective commercial Crew Transportation System to the Low Earth Orbit market. ULA is assisting SNC with integrated aerodynamics and risk retirement. Aerojet, a propulsion leader, is developing the main Reaction Control System. Draper Lab, with unparalleled GN&C experience, is leading orbital Guidance Navigation &Control development. NASA's Langley Research Center adds expertise in HL–20 analysis and modeling, while NASA's Dryden Flight Research Center adds flight test expertise for our extensive flight test program. In fact, we are using the expertise from seven NASA Centers to ensure we are building the best spacecraft possible. AdamWorks is assisting SNC in structural fabrication using our combined composite manufacturing capabilities. The University of Colorado is applying young minds to conduct displays and controls layout and evaluations and refine the integrated system Human Rating Plan, with assistance from Special Aerospace Services. United Space Alliance is using their extensive Space Shuttle experience to provide operations and software development support. SNC and Virgin Galactic are working together to plan for global marketing, sales, and commercial operation of the orbital Dream Chaser. In addition to coordinating and managing the team, SNC manages all internal systems, propulsion, structure, Launch Vehicle integration, and systems engineering. This superb team of experienced space companies allows us to use heritage hardware and software to rapidly develop our space system and provide a cost effective and safe way to transport people to and from low Earth orbit.

Dream Chaser Space System

Our primary Dream Chaser Space System goals are to safely, reliably, and cost effectively transport crew to the International Space Station and return to a hard surface runway. The heritage Dream Chaser design evolved from the NASA Langley Research Center's HL–20, which was originally derived from the Russian BOR–4 orbital test vehicle that flew 4 orbital flights. Langley performed more than 1,200 wind tunnel tests, wrote 60 journal papers and NASA contractor reports, and performed thousands of piloted simulations in its decade-long investment refining HL–20 aerodynamics, performance, and controls. To take advantage of the orbital flight and wind tunnel heritage, SNC retained the HL–20 design center of gravity limits and outer mold line, but made significant upgrades in composite structures so as to take advantage of modern construction techniques and materials and we incorporated a new safer, more operable, flexible propulsion capability. Bottomline, SNC consolidated the fragmented HL–20 aerodynamic data, filled in the database gaps with significant additional analysis, and have designed a very sophisticated reusable space plane that can satisfy NASA's low Earth orbit needs.

The Dream Chaser vehicle features a reusable, piloted lifting body design capable of transporting two to seven persons and pressurized cargo. Dream Chaser orbital missions are launched on an extremely reliable Atlas V 402 booster rocket and return to land on a conventional runway. The baseline launch site is Kennedy Space Center and the baseline landing site is the Shuttle Landing Facility. But, The Dream Chaser is designed to be able to reach and land on any 10,000 foot hard surface runway for any nominal or abort landing. The DC is almost entirely reusable, with exception of some propulsion system components and the chemical batteries. Post-flight Dream Chaser spacecraft refurbishment and launch processing will occur at the Kennedy Space Center prior to re-flight certification.

The Dream Chaser spacecraft has the capability for launch pad abort and intact ascent aborts from any point on its trajectory to hard surface runways. The Dream Chaser spacecraft's > 1,100 nautical mile cross-range capability is significantly better than the typical capsule cross range. Every-orbit deorbit to runway landing capability exists for emergencies and there is sufficient cross range to accommodate multiple daily Continental U.S. runway landing opportunities. Low 1.5 g entry loads are considerably less than those experienced by capsules during reentry which allows Dream Chaser to have large down-mass capability for g-sensitive science experiments and touchdown shock is far lower than capsule loads which can be as high as 15 g's for water landing (e.g., Apollo 12 and 15). These reduced loads lessen the possibility that a vehicle will require post-mission repair for re-flight. Runway landings avoid expensive ship-based recovery and salt water exposure.

We selected the reliable Atlas V launch vehicle specifically for its heritage, demonstrated reliability, ability to human rate, and compatibility with the DC spacecraft. This Nation has launched multi-billion dollar national assets on the Atlas due to its reliability. The Atlas has demonstrated 98 consecutive successes since 1993, including a 100% mission success record for all Atlas II, III, and V flights, with all spacecraft reaching proper orbit.

After nominal orbital insertion, Dream Chaser is reconfigured for orbital operations to support crew Flight Day 2 rendezvous and docking. Orbit adjust is performed using the SNC-developed on-board hybrid rocket motors and reaction control system. The hybrid motors are improved versions of the successful SNC developed SpaceShipOne rocket motors. This technology is also being used on the SpaceShipTwo program resulting in extensive flight heritage and experience before our first orbital flight. The DC is designed for 3.5 days of on-orbit loiter without ISS docking. The DC is designed to dock to the NASA Docking System (NDS) located at appropriate ISS docking locations.

The DC provides assured crew return capability while docked to the ISS. DC can remain docked to ISS for extended periods (up to 210 days, assuming the DC shares ISS cabin atmosphere while docked and receives ISS power transfer to support battery trickle charge).

Dream Chaser Space System Accomplishments to Date

The following milestones were completed from December 2009 to September 2010 during the Commercial Crew Development Program, Phase 1 contract (CCDev1):

Milestone 1: Program Implementation Plan Delivered. This included management planning for design, development, testing, and evaluation supplier engagement, risks and anticipated mitigations.

Milestone 2: Space Vehicle Manufacturing Review of Aeroshell Tooling. This included manufacturing the aeroshell tooling, a review of the aeroshell design,

manufacturing plans, and readiness to begin fabrication of the Dream Chaser's aeroshell.

Milestone 3: Space Vehicle Prime Motor Manufacture and Multiple Restart Firings. This milestone include manufacture of and ground based motor firings of a single hybrid motor with 3 restartable firings for a minimum duration of 5 seconds for each firing, including one firing in a vacuum condition.

Milestone 4: Space Vehicle Primary Structure Testing. In this milestone the Dream Chaser's primary structure was designed, fabricated, assembled, and tested to support landing gear and hybrid motor thrust loads.

All milestones were completed on time and under budget.

In addition to these milestones, The Dream Chaser spacecraft went through extensive aerodynamic, thermal protection system, guidance, navigation, and control system analysis. We completed development of our desktop simulator, completed extensive systems engineering, developed a risk management plan, a human rating plan, and significant program documentation to support further Dream Chaser development.

Since we finished our four milestones under budget during CCDev1 and because of our commitment to the success of this program, we added multiple unfunded milestones. We designed, developed, and successfully flight tested a scale model of the Dream Chaser spacecraft, dropped from over 14,000 feet at the NASA Dryden Flight Research Center. This flight test signaled the beginning of the atmospheric test program for the Dream Chaser vehicle. We also developed our first simulator to begin engineering development simulations, and built several mockups to use for engineering development.

We are currently six months into the CCDev Phase 2 contract (CCDev2). The following milestones have been completed (or are about to be) in the CCDev2 program:

Milestone 1: System Requirements Review. Presented a briefing and plan of the overall system requirements for the Dream Chaser Space System.

Milestone 2: Canted Airfoil Fin Selection. Complete wind tunnel tests and Computational Fluid Dynamics analysis on candidate airfoil fin outer mold line and select final fin shape to ensure proper aerodynamic performance of fins.

Milestone 3: Cockpit Based Flight Simulator. Complete fabrication and assembly of cockpit structure, install simulator designs and controls, and conduct a Simulator Readiness Review to verify readiness for engineering and pilot evaluations.

Milestone 4: Vehicle Avionics Integration Laboratory (VAIL). Design, manufacture, and integrate the VAIL to support testing, verification, and validation of Dream Chaser avionics and software.

Once again, all completed milestones were finished on schedule and under budget, with remaining funds being re-invested to accomplish additional work to accelerate our program.

Remaining Milestones in CCDev2 and road to Critical Design Review

Milestone 5: System Definition Review. Conduct Dream Chaser System Definition Review, which completes the first design cycle of the Dream Chaser Space System architecture and design. **This milestone will be completed on Oct 27, 2011—on schedule.**

Milestone 6: Flight Control Integration Laboratory. Design, manufacture, and integrate the flight control integration laboratory to begin developmental engineering tests of flight control actuators and surfaces. Complete test hardware such that it is ready to support Engineering Test Article flight control tests. **This milestone will be completed on Nov 17, 2011—on schedule.**

Milestone 7: Engineering Test Article (ETA) Structure Delivery. Complete assembly and deliver the ETA primary structure for start of systems integration and installation of secondary structures. Scheduled for completion in Dec. 2011.

Milestone 8: Separation System Test. Complete design and construction of the prototype Dream Chaser separation system and demonstrate activation to validate concept and verify performance of the separation system. Scheduled for completion in Feb. 2012.

Milestone 9: Preliminary Design Review. Conduct Preliminary Design Review of the Dream Chaser Space System. This review will complete the second design cycle of Dream Chaser Space System. Scheduled for completion in May 2012.

Milestone 10: Captive Carry Interface and ETA Landing Gear Drop Tests. Complete fabrication of the ETA captive carry prototype mechanism and perform release test to verify performance of system to ensure readiness for captive carry. Perform drop test of ETA landing gear to evaluate landing gear dynamic limit loads and landing load attenuation capability to ensure adequate performance of landing gear. Scheduled for completion in Jan. 2012.

Milestone 11: ETA Captive Carry Flight Test Readiness Review. Complete Captive Carry Flight Test Readiness Review to verify ETA readiness for captive carry testing. Scheduled for completion in March 2012.

Milestone 12: ETA Captive Carry Flight Test. Conduct ETA captive carry flight test on carrier aircraft to characterize integrated vehicle performance. Schedule for completion in April 2012

Milestone 13: ETA Free Flight Test. Conduct unpiloted ETA Free Flight Test from carrier aircraft to characterize handling qualities and approach and landing. Scheduled for completion in July 2012.

At the completion of the Preliminary Design Review in May of 2012, the Dream Chaser team will begin Design Cycle 3, which will culminate in our CDR (Critical Design review) in the mid to late 2013 timeframe. During this design cycle, all systems will be matured through design, analysis, building of flight-like hardware and extensive testing—culminating in subsystem CDRs to support the overall system CDR. We will build a Structural Test Article for further loads testing, and continue test flights, both unpiloted and piloted in the Engineering Test Article. Additionally, we will build our Suborbital Vehicle and complete powered flight tests to validate and verify Guidance, Navigation, and Control in the low supersonic region. The Suborbital Vehicle flight test program will conclude with a Pad Abort test to runway landing.

NASA's Commercial Crew Program: Procurement Strategy Challenges

A common question often asked about NASA's commercial crew program is "How can commercial companies build and provide spacecraft for crew transportation in and out of low earth orbit?" The answer to this question is that commercial companies have been doing this for the past 50 years. Every single United States human-rated spacecraft has been built by a commercial company. Companies such as McDonnell Aircraft Company, prime contractor of the Mercury capsule, to Rockwell International, builder of the Space Shuttle orbiter, to current companies like Sierra Nevada which are today developing new crewed spacecraft. Other spacecraft developed in the future for beyond earth orbit missions will also be built by commercial companies.

So what's different about what we are doing when compared to previous human-rated spacecraft programs? There are two primary differences—the procurement mechanism, and how NASA and our companies interact. Under the current Commercial Crew Development program, the contractual mechanism is the Space Act Agreement—a fixed price, pay for performance, milestone based program. Space Act Agreements are easy to implement, easy to change, and easy to terminate. If companies don't stay on schedule or milestones aren't met, then companies aren't paid. Companies are also expected to contribute financially to the program. Losses to the government for a non-performing company can by minimized through the use of milestone-based payments, and cost overruns are simply not possible. The next phase of the Commercial Crew Program is planned to be a FAR based contract that will retain many of the good things about SAAs, including fixed-price and milestone-based payments. These types of contracting mechanisms are a cost effective way for the government to retire technology development risk and mature an integrated design.

Interaction between NASA and Sierra Nevada on our Space Act Agreements has evolved into a very unique partnership. Typical government interaction with commercial companies building spacecraft involves providing guidance, receiving insight into our design, and having oversight over our requirements. Guidance has been provided to us by NASA in the form of spacecraft system requirements and specifications, just as in traditional contracting approaches. We are required, in the end, to meet those requirements and specifications or NASA simply won't contract for our services. To accomplish the insight function, NASA has embedded a 'Partner Integration Team' of human spaceflight experts directly into our company to provide a true inside view of our day-to-day operations. They share offices with us and attend all of our meetings, allowing complete government insight into the development work we are doing. This has the dual advantage of removing many of the burdensome day-to-day reporting requirements, while at the same time providing our team

with valuable government advisors and consultants as we work together to build a new spacecraft.

Insight versus Oversight

In the next phase of the Commercial Crew Development Program, the proposed contracting mechanism is a firm fixed price Federal Acquisition Regulations-based contract. While the complexities of this type of contract will be much greater than the current Space Act Agreement milestone-based contract, the insight and oversight model shouldn't change significantly for Sierra Nevada. During the current CCDev2 contract, we have allowed complete NASA insight into our day to day operations. NASA technical experts are embedded within all of our design, development, and test teams—providing both expert advice to us as well as critical insight to NASA's Commercial Crew Program. This approach has proved to be very effective—requiring less oversight due to the extraordinary level of insight.

The challenge with this next phase of the program will be to balance oversight versus insight. For example, NASA should provide oversight and direction in all cases where they see a need to improve the safety of a spacecraft being developed for their use. However, that does not mean that every technical change suggested by the government should be accepted. If a change makes the design 'better' but doesn't impact safety, then the commercial company must have the leeway to accept or reject the change, based on technical, cost, and/or schedule considerations. This is where the partnership between NASA and a commercial company that is truly responsible for the technical design of a crewed spacecraft can make a huge difference—keeping costs and schedule under control while at the same time developing the safest spacecraft possible for the defined mission.

The future Low Earth Orbit commercial market

The SNC business case is strong. We have performed multiple internal and external market research studies during our six-year Dream Chaser program. We are developing multiple potential markets for our Crew Transportation System, many of which are best serviced by a lifting body such as ours. These markets are human transportation, critical cargo transportation, orbital servicing, and orbital sensor and testbed operations. Five primary client groups include: NASA and other civil agencies, commercial space corporations, military agencies, international markets, and tourism. NASA and crew transportation to ISS will be the anchor tenant for Dream Chaser, but after an early start-up period will not be the major revenue provider. SNC, through its expanding operations expects to place hundreds of satellites in orbit during the next few years and will become its own servicing client. All of our markets are expected to grow substantially and are not limited in time. SNC will develop a number of Dream Chaser vehicles from the same platform, similar to an airplane platform like the 747 or C–130, with each variant optimized for the specific mission. Virgin Galactic recognizes the market for the DC and they have joined our team to begin marketing and sales of orbital human transportation services.

A key advantage of the Dream Chaser is the ability to land on a runway, allowing for many viable orbital and suborbital missions to be accomplished. The spacecraft has substantial pressurized cargo down-mass capability with low g reentry and runway landing at many landing sites. It can be adapted from a full seven-person crew to two crew members with increased cargo capacity to fully autonomous operations. It is also scarred for potential future servicing Extra Vehicular Activity capability and robotic manipulator use. Our low stress runway landings will allow us to carry the greatest range of passengers, and provide researchers with the best possible path for maintaining the integrity of their experiments through a low-g return and quick access to science samples. Our non-toxic propellants and runway landing capability allow us to land at domestic and international locations without special services. We are currently refining our business model to capture variables such as market share, seat price, and launch vehicle price while considering parameters such as turnaround time and fleet size. This will allow evaluating the sensitivity to market and technical factors.

We have a dedicated business development team who sell SNC space services and products around the world. This team has relationships with future customers who we periodically brief on our Dream Chaser progress, receiving in return information on their needs and future missions. Our relationship with Virgin Galactic will allow utilization of its existing marketing infrastructure for the SpaceShipTwo program to rapidly develop critical non-NASA global markets for the Dream Chaser Space System.

Chairman HALL. And we thank you. And five words, on time and under budget, are things we listen for. Thank you very much.

I recognize Mr. Elon Musk for his statement.

STATEMENT OF MR. ELON MUSK,
CEO AND CHIEF TECHNOLOGY OFFICER,
SPACE EXPLORATION TECHNOLOGIES CORPORATION,
HAWTHORNE, CALIFORNIA

Mr. MUSK. Chairman Hall, Ranking Member Johnson and Members of the Committee, thank you for the opportunity to be here today.

The American endeavor in space is uniquely inspirational, and human spaceflight is one of the great achievements of humankind. Although NASA only sent a handful of people to the moon, in a sense we all went there vicariously. We shared in the invention and profound achievement. Those are the things that make life worth living.

The goal of SpaceX and our more than 1,500 employees is to advance the course of space so that many more may experience the great adventure of space exploration. I have to say, it is actually not, as some may assume, to maximize profit. That is why I have retained a majority ownership of the company to ensure that the idealistic goals of SpaceX remain true.

We are very proud of our partnership with NASA, with whom we share the success that we have achieved to date. SpaceX would not have been able to get started without the work of NASA nor would we have been able to achieve the point we have achieved today without the great help of NASA. They are a partner in the truest sense.

Soon we will see Dragon become the first commercial spacecraft in history to deliver cargo to the space station, and that may come as soon as January of next year.

Mr. Chairman, if I may show a small video?

Chairman HALL. Without objection.

[Video playback.]

Mr. MUSK. This is not a simulation. That is the view that an astronaut would have on our spacecraft.

I would like to focus on three areas: safety, affordability and of course our partnership with NASA as it relates to commercial crew. Safety is paramount. Safety is always first. There is no more important responsibility than transporting the heroes of America's astronaut corps into space. For many years, Mr. Chairman, you have rightfully championed the development of launch abort capabilities for astronauts in the event of a launch failure. This is of critical importance. In fact, to that end, our efforts on CCDev2 today have focused very heavily on launch abort capabilities. In fact, later this year we intend to demonstrate a launch abort engine, which I think will be quite exciting.

Our focus on safety is reflected throughout the vehicle in both the Falcon 9 launch vehicle and Dragon's basic designs. Because our goal from day one has been to carry astronauts, every design choice is made with crew in mind. In fact, Dragon is fully equipped to handle crew habitation today since astronauts will board Dragon

while it is berthed with the space station for our cargo resupply missions.

Our upcoming cargo missions will provide significant flight experience on the Falcon 9 and Dragon systems so the first time that astronauts fly will not be the first time that the vehicles fly. In fact, they will have flown perhaps as many as a dozen times before astronauts first step foot on our spacecraft. We expect the launch vehicle to fly even more often as we have over 35 missions under contract for our Falcon 9 launch vehicle.

With respect to the CCDev2 program itself, we are leveraging our partnership with NASA to accelerate development of our integrated launch abort system that flies with Dragon throughout its mission and will for the first time provide launch abort capability all the way to orbit. This has not been the case with prior systems. NASA in fact recently approved our preliminary design review of our launch abort system components, so we have made some good progress in this direction.

We believe we are on track to carry astronauts to the space station in approximately three years. Of course, that does depend to some degree on the funding that is allocated to commercial crew, but we remain committed to the public statement that I have been making for a while, which is that within three years we will be able to carry astronauts to the space station and do so safely.

It is good that NASA's effort for the third phase of commercial crew development will be firm fixed price and milestone-based. It is much better for the government to define the standards and the ultimate goal than to actually do the design itself. If you ask engineers to figure out a good solution, tell them the goal rather than the method, and I think that is a very good direction in that respect. I hope the final RP4 commercial crew will indeed reflect the best aspects of the public-private approach that has been employed under COTS and CRS to date.

Second to safety and reliability as a competitive commercial company, affordability is obviously extremely important. This has been raised by Ranking Member Johnson as well as Chairman Hall and many others. Because we have produced by doing both cargo and crew with a vehicle that is substantially similar, we are able to leverage the costs and divide the costs over a larger number of missions. Instead of it perhaps being over two missions per year, it is actually going to be over six or even eight missions per year. This allows for a dramatic reduction in costs while maintaining high reliability. And of course, because our launch vehicle is being used to fly many commercial satellites as well, there is an even greater allocation of cost. Of the roughly $3 billion that SpaceX has been awarded to date in contracts, only about half is from NASA, so there is significant support from the private sector. In fact, to this point it is over 50 percent in terms of revenue. So this I think proves that space exploration can be achieved affordably.

We look forward to continuing our partnership with NASA to quickly end our reliance on Russia for human spaceflight and fully realize the scientific potential of the space station. Harnessing the power of American free enterprise, which I think is one of the most powerful forces on earth, is the way to achieve these goals on budget and on time. Thank you.

[The prepared statement of Mr. Musk follows:]

PREPARED STATEMENT OF MR. ELON MUSK, CEO AND CHIEF TECHNOLOGY OFFICER, SPACE EXPLORATION TECHNOLOGIES CORP., HAWTHORNE, CA

Chairman Hall, Ranking Member Johnson and Members of the Committee,

On behalf of Space Exploration Technologies (SpaceX) and our more than 1,500 employees across the United States, thank you for the opportunity to participate in today's hearing.

I also want to thank you and the members of the Committee for your continued support of NASA and America's space exploration programs. The goals of this agency, unlike nearly any other, are focused on advancing the state of human knowledge and human achievement. Even as we face tough fiscal challenges as a Nation, NASA and the cause of space exploration deserve support, particularly through efficient investments and public-private partnerships that provide best value for the taxpayer.

America's endeavors in space are truly inspirational. I deeply believe that human spaceflight is one of the great achievements of humankind. Although NASA only sent a handful of people to the moon, it felt like we all went. We vicariously shared in the adventure and achievement. My goal, and the goal of SpaceX, is to help create the technology so that more can share in that great adventure.

With your support and NASA's invaluable partnership through the Commercial Orbital Transportation Services (COTS) program, SpaceX made history last year as the first commercial company to successfully recover a spacecraft from Earth orbit. The inaugural flight of the SpaceX Dragon confirmed what we have always believed—the responsiveness and ingenuity of the private sector, combined with the U.S. government's investment and technical support, can deliver an American spaceflight program that is safe, achievable, sustainable and affordable.

SpaceX is honored to continue our partnership with NASA as we work together to develop commercial crew capabilities. Our goal is to develop the safest, most reliable and affordable crew transportation system to low Earth orbit and, ultimately, beyond. Indeed, carrying humans into space has been a cornerstone of SpaceX's vehicle designs from the day the company was founded. There is no more critical and precious responsibility than having the opportunity and privilege to transport the true heroes of America's astronaut corps into space and, in the event of a mishap or failure, providing them with an effective, life-saving abort capability. This awesome responsibility informs and shapes SpaceX's every design, decision and operation.

Mr. Chairman, the United States needs safe and affordable domestic systems for transporting American astronauts into space. Most pressing is the need to restore our ability to carry crew to the International Space Station (ISS) for which the country has spent so much effort, sweat and national treasure. The ISS's research and scientific potential is constrained by the current inability to achieve a full complement of astronauts on board. Sole reliance on the Russian Soyuz is not a remedy.

With our NASA colleagues, SpaceX is working hard to deliver a solution. I am pleased to provide the Committee with an update on SpaceX's human spaceflight advances to date and challenges ahead as we progress toward the capability to transport human beings into space aboard the Falcon launch vehicles and Dragon spacecraft.

I. Commercial Cargo Efforts Leading to Crew Carriage

In 2006, SpaceX partnered with NASA under the Commercial Orbital Transportation Services (COTS) program. The COTS program was the first of its kind for NASA: a "pay for performance" partnership between the government and private business to rapidly design and prototype critical technologies. NASA structured the COTS program as a collaborative venture with commercial space companies—sharing the risks, costs and rewards of developing new space transportation capabilities. That "experiment" resulted in the first U.S. launch vehicle developed since Saturn with engine out reliability. As demonstration of its reliability, this launcher flew successfully for its first two missions. This reliable launcher is also the only U.S. launch vehicle that is competitive in the international marketplace and will help bring launch dominance back to the U.S. This experiment also resulted in a reusable spacecraft that will service our critical national asset—the ISS.

One of the central tenets of the COTS program is that public-private partnerships leverage private capital to supplement government dollars, yielding products and services more cost-effectively and more rapidly. In pursuing its mission to create "new commercial space transportation systems and demonstrate capabilities to pro-

vide cost-effective transportation services to orbit," NASA's COTS office granted its partners "latitude to freely innovate and optimize their launch vehicle and spacecraft designs and operations." [1]

That latitude fostered SpaceX's ability to focus on safe, simple, proven designs that are cost-effective. As a result, SpaceX developed the Falcon 9 rocket for a fraction of the cost NASA would have paid under a traditional acquisition model. NASA's internal studies using the NASA–Air Force Cost Model (NAFCOM) concluded that it would have cost NASA $1.7B to $4B to develop the Falcon 9 rocket. By contrast, in partnership with NASA's COTS program, SpaceX developed the Falcon 9 for approximately $300M. [2] It bears noting that the Falcon 9's development included designing, building and testing SpaceX's Merlin engine, the first new all-American hydrocarbon engine for an orbital booster in forty years.

Likewise, SpaceX developed the Dragon spacecraft—a free-flying, reusable spacecraft—from a clean sheet of paper to the first demonstration flight in just over four years for about $300 million.

a. SpaceX's COTS Flight Success and Upcoming Launch

In June of last year, SpaceX performed a successful demonstration launch of the Falcon 9 on its maiden voyage. Then, on December 8, 2010, SpaceX successfully launched the Falcon 9 with the Dragon spacecraft, becoming the first commercial company in history to launch, reenter and successfully recover a spacecraft from Earth orbit. SpaceX's COTS demonstration mission blasted off from Launch Complex 40 at Cape Canaveral. The Falcon 9 lofted the Dragon to orbit where it twice circled the Earth and then reentered the Earth's atmosphere, splashing down safely in the Pacific Ocean. Until late last year, launching, orbiting, reentering and recovering a spacecraft was a feat previously performed by only six nations or government agencies: the United States, Russia, China, Japan, India and the European Space Agency. NASA's expert advice and mentorship throughout the development process helped SpaceX build upon 50 years of U.S. space achievements to reach this goal.

In preparation for the next COTS demonstration mission, which is set to occur in the next few months, the Dragon spacecraft design has been upgraded to meet all requirements for ferrying cargo to and from the ISS, including the proximity operations sensors to guide the vehicle safely near the ISS. This mission will be an extended mission to the ISS, lasting more than three weeks. Consequently, two solar array wings have been added to the Dragon trunk to enable positive power generation throughout the flight. Additionally, a redundant active thermal control system loop has been installed in the Dragon trunk to reject excess heat into space; protect the spacecraft from excessively hot or cold temperatures; and provide an environment inside the spacecraft that is acceptable for cargo and for the ISS crew when berthed to station.

In accordance with our COTS milestones, a series of tests have been conducted on the fully integrated Dragon spacecraft, including a 12-day thermal vacuum test during which, the entire avionics system was exercised while flowing telemetry 24/7. (No notable issues were uncovered and the thermal data matched model predictions closely.)

Dragon's proximity sensors are critical for the ISS approach and have been put through extensive performance testing in open loop and closed loop simulation using flight hardware and software. Significant testing emphasis has also been placed on the new Dragon mechanisms, which have all completed qualification testing. These mechanisms include the forward hatch, solar arrays, guidance, navigation and controls (GNC) bay door that exposes the Flight Releasable Grapple Fixture (FRGF) and a claw that provides electrical and data connections between the capsule and trunk.

Several joint SpaceX–NASA tests have been completed, including the Passive Common Berthing Mechanism (PCBM) testing and cabin acoustic noise verification. Most recently, the vehicle completed radiation testing of all avionics components and an Electromagnetic Interference (EMI) test in keeping with NASA requirements.

We are rapidly progressing toward the next COTS demonstration flight and are still engaged with NASA to finalize vehicle verifications and the mission plan. This next COTS mission represents a huge milestone not only for SpaceX, but also for NASA, the U.S. space program and American free enterprise. When the astronauts

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[1] NASA COTS video, www.nasa.gov

[2] NASA independently verified SpaceX's total development costs of both the Falcon 1 and Falcon 9 at approximately $390 million in the aggregate ($300 million for Falcon 9; $90 million for Falcon 1). NASA, *Falcon 9 Launch Vehicle NAFCOM Cost Estimates, August 2011.*

stationed on the ISS open the hatch and enter the Dragon spacecraft for the first time, it will mark the beginning of a new era in space travel.

b. Commonality between Cargo Falcon 9/Dragon and Crew Falcon 9/ Dragon

SpaceX conceived the Falcon 9 and Dragon with crew carriage in mind and undertook designs from inception to meet human certification requirements, including increased structural factors of safety, triple-redundant avionics, trajectories with acceleration limits within human safety limits, and many others. Because SpaceX planned for the current cargo Dragon to evolve into a crew version, many of the Dragon's systems are identical in the cargo and crew versions. In fact, Dragon was designed to meet NASA's human engineering safety requirements in SSP 50808 because the cargo Dragon will fly in close proximity to the ISS, berth with the ISS and support on-orbit crew habitation during cargo transfer operations.

Designed to be as safe as possible from a clean sheet in 2005, the Dragon crew transportation system takes advantage of 21st century technology advances and lessons learned throughout the history of human spaceflight. The Dragon spacecraft is comprised of three main elements: the Nosecone, which protects the vessel and the docking adaptor during ascent; the Spacecraft, which houses the crew and/or pressurized cargo as well as the service section containing avionics, the Reaction Control System (RCS), parachutes and other support infrastructure; and the Trunk, which provides for the stowage of unpressurized cargo and will support Dragon's solar arrays and thermal radiators.

As a result of the commonality between the cargo and crew versions of Dragon, many of the critical components of the Dragon crew transportation system are already operational and flight-proven. Other systems for crew accommodation require some development, but the only major development is for the launch abort system. This commonality enables SpaceX to plan for crew demonstration flights in 2014, with a rapid transition to operational capability.

c. Lessons Learned from the COTS Program Model

The NASA–SpaceX COTS partnership has successfully enabled and promoted genuine innovation while maintaining safety and reliability standards. The COTS program helped guide the development of Dragon and Falcon 9 to pass a set of specific requirements and verifications required for any ISS visiting vehicle, but left the design and aspects of analysis and testing largely to the contractor. This allowed for rapid prototyping and design iterations in which components could be designed, tested, modified and retested, often times in a matter of hours. And NASA could be confident in the final design because all design and test data were available for review. Also critical for innovation was the fact that decisions about "how to meet the requirements" were generally left to the contractor. Rather the critical metric was that the requirement was clearly met. I note here that specificity as to how to meet requirements is inherently prescriptive and often results in less innovation.

Safety and reliability standards have been maintained through insight into the entire system design and insight and oversight into safety critical systems. Systems that interface with the ISS are thoroughly reviewed by independent contractors, NASA employees providing regular and ongoing support, formal NASA panels and other subject matter experts. These safety-critical systems are also subject to strict requirements and verifications that ensure they will function as intended.

Overall, this teaming approach with NASA has proven invaluable. NASA has a wide array of resources and deep technical expertise that was generally made available in a partnership approach. Testing facilities, analyses, subject matter experts and a host of other contributions helped solve difficult technical problems, improve the safety and robustness of vehicle and help advance innovative approaches.

II. Commercial Crew Development Efforts: CCDev2 and Flight by 2014

The goal of SpaceX's crew transportation system is to safely and reliably transport up to seven crew members from our launch pad on Cape Canaveral to the ISS, dwell on the ISS for up to 210 days and return the same number of crew safely to Earth. A two-stage, liquid oxygen and kerosene launch vehicle, the Falcon 9 possesses robust reliability features. The nine SpaceX Merlin engines that power Falcon 9's first stage provide engine-out reliability from liftoff—a feature not offered by the Russian Soyuz—and the engine's turbopumps run at lower pressure, making them more resistant to failure from foreign object debris (FOD) ingestion. The Dragon offers improved avionics redundancy and failure tolerance compared to Soyuz's single gyroscope and accelerometer.

SpaceX selected the Dragon design so that it would be naturally stable entering the earth's atmosphere, thereby maximizing the chances of a safe return to Earth

even in the event of the vehicle's control systems' total failure. Other features vital to the cargo Dragon's ability to safely reenter Earth's atmosphere, such as the PICA–X heat shield, are already integrated into the Dragon capsule and will gain significant flight heritage during the Commercial Resupply Services (CRS) missions.

In the coming years, SpaceX will collect significant data and experience on the Falcon 9 and Dragon system from upcoming COTS and future CRS missions. Specifically, the Dragon spacecraft and Falcon 9 launch vehicle are currently scheduled to fly together at least eight more times before a crew demonstration in 2014. The Falcon 9 itself is scheduled to launch a total of 14 missions prior to the first Dragon crew mission. The commonality between the cargo and crew versions of Dragon allows for significant end-to-end flight heritage and operational experience to be gained on critical functions—including launch, navigation and control, thermal protection, thermal control, power generation and distribution, avionics, software, entry guidance and recovery—well before the first crew flight. The avionics hardware is highly scalable, allowing SpaceX to significantly leverage the architecture tested and proven on cargo missions for use on crew missions.

Crew transport launch operations are similar to our cargo transportation launch operations inasmuch as they will take advantage of the safety, reliability and availability benefits of the "aircraft-like" operations of the Falcon 9. For example, full-stage static fire tests, similar to an aircraft ground run-up, are performed prior to each launch. During terminal countdown, the Falcon 9 throttles up to full power before being released for liftoff, allowing anomalies during engine startup to be safely mitigated. The Falcon 9 can support multiple full-thrust static fires and engine aborts without need for refurbishment, allowing for true "test-like-you-fly" operations. Additionally, Falcon 9 avionics support hardware-in-the-loop testing to prove out flight software in the actual flight hardware configuration.

a. CCDev 2: the Criticality of Launch Abort Systems

Under NASA's Commercial Crew Development II (CCDev 2) program, SpaceX has opted to focus on accelerating the development of an efficient, life-saving launch abort system (LAS). SpaceX's crew Dragon includes an integrated LAS, which we believe will yield numerous safety and performance benefits. The Dragon's LAS is carried through orbit and reentry, with the abort systems available for use throughout the time the Dragon is boosted into space. Carrying the abort system all the way into orbit also eliminates the jettison of the abort system as a required event for the safe completion of a nominal mission.

SpaceX is further addressing launch vehicle malfunction detection and initiation of automated aborts as well as developing the necessary LAS engine hardware to implement such a design. This development will culminate in a series of engine tests to demonstrate safety, reliability, maximum thrust, minimum thrust, throttling capability, throttling rate and specific impulse.

The Dragon LAS is a vehicle-integrated, side-mounted engine system selected for its safety, reliability and performance after a system-level analysis conducted by SpaceX. Eight abort engines (known as SuperDracos because they are modified versions of Dragon's existing Draco thrusters) are located around the periphery of the Dragon service section and fed by hypergolic propellant stored in the spacecraft propellant tanks. SuperDracos will carry the spacecraft away from the booster and are capable of separating the Dragon crew spacecraft from a failing booster while on the pad all the way through nominal on-orbit separation of Dragon from the second stage.

The LAS will be enabled after crew ingress and securing on the pad and will be disabled on orbit after Dragon separation from the second stage. The launch vehicle malfunction detection system for automatic abort will monitor the Falcon 9 and Dragon for engine failures, flight control failure, failure of the booster propellant tank and failure of the booster's primary structure, among other signatures.

Abort responses will be determined by failure(s) detected and the phase of flight, in order to maximize survivability. For example, a significantly off-nominal change in tank pressure while the vehicle is on the pad may result in an instantaneous high-acceleration abort, while a performance-related failure of the second-stage engine during ascent may result in a delayed abort until ideal entry conditions are met, a pre-abort shutdown of the second-stage engine and a low-acceleration abort profile.

Ultimately, this technology, research, design and intellectual effort are about one thing: protecting human life. No one has summed it up better than Garrett Reisman, former astronaut and one of the heads of development for the Dragon LAS at SpaceX, who said, "We are not going to design a vehicle that I wouldn't strap myself or my friends into."

b. CCDev 2: Successes To Date and Approach Going Forward

To date, SpaceX has successfully completed four of the ten milestones in our CCDev2 Space Act Agreement (SAA) for a total of $40M of the $75M under SpaceX's CCDev2 agreement. The first three milestones included a detailed program plan roll out, LAS propulsion Conceptual Design Review, Design Status Review and LAS Components Preliminary Design Review (PDR). In successfully meeting those milestones on schedule and on budget, SpaceX provided NASA with comprehensive Falcon 9/Dragon crew systems concept design insight including cabin layout, seat design, space suit design, life support system design, abort scenarios, concepts for the launch abort system, ground systems, abort trajectories, aerodynamics of ascent and entry and mass margins. The Design Status Review provided an opportunity for SpaceX to work with both NASA and industry teammates as partners and make desired crew systems design concept changes after peer review and feedback on the system-level designs and concepts.

With regards to the LAS components PDR, our most recently completed milestone, SpaceX engineers demonstrated to NASA's satisfaction that the maturity of the LAS propulsion components design is appropriate to support proceeding with detailed design, fabrication, assembly, integration and test of LAS propulsion components test articles. We also provided evidence that the LAS propulsion design meets all system requirements with acceptable risk and can be developed within schedule.

Going forward, milestones will include abort engine fabrication and testing and further maturation of the vehicle system design and concept of operations. In addition, design and construction of a test facility for the launch abort engine is underway at the SpaceX rocket test facility in McGregor, Texas. The remaining hardware milestones will culminate in all key launch abort system propulsion components undergoing initial fluid and environmental development testing. Here, the SuperDracos will be hot-fire tested for a full duration. We will also demonstrate throttle capability, which is essential for abort maneuvers.

With respect to the crew systems design efforts, SpaceX will incorporate feedback from NASA and industry partners, present safety and mission assurance studies and provide a draft of the Vehicle Certification Plan (the path forward for getting crew flights certified by NASA). SpaceX is also investing in two self-funded milestones for crew cabin development with engineering prototypes of the cabin layout including seats where NASA astronaut trials will provide feedback on cockpit design.

c. CCDev 2: Designing Crew Accommodations for the Dragon

In parallel with the design and development work on the launch abort system engine and components, SpaceX is working on the design of other systems necessary to carry astronauts in the Dragon spacecraft. These systems include seats, spacesuits, an environmental control and life support system, displays and controls and ground systems.

SpaceX is designing the Dragon to carry seven crewmembers seated in two rows. The seats will be conformal and a mechanical force accommodation system will cushion any off-nominal landing impacts to assure crew safety. The crew will wear spacesuits to protect them from any rapid cabin depressurization emergency event. The suits will be rated for operation at vacuum and provide communication and cooling systems.

The Dragon environmental control and life support systems will provide the crew with fresh air ventilation, remove carbon dioxide and control humidity and cabin pressure. Fire detection and suppression systems will protect the crew in the event of an emergency. Accommodations will be provided for food preparation and waste disposal.

During the span of the CCDev2 SAA, SpaceX is completing preliminary designs on modifications to our launch pad and mission control center to be ready to fly astronauts. The launch pad will have a new tower and access arm to allow crew to enter the Dragon and egress quickly in the event of a launch pad emergency. Mission control will have a new console position for a flight surgeon for human missions.

In addition to these crew vehicle systems, the operation of the vehicle for nominal, contingency and emergency situations is being outlined for all phases of flight. A crew cabin mock-up is being constructed to allow NASA astronauts to evaluate crew accommodations and other human factors considerations. We are conducting preliminary designs for crew display and manual control hardware. The detailed operation of the launch abort system is also being characterized by defining abort modes, triggering events and abort trajectories. Finally, the safety and mission assurance analyses are being evaluated with the goal of ensuring that the Dragon and Falcon 9 vehicle will achieve a level of safety better than any human spacecraft ever flown.

This work on crew accommodations, along with the design and development of the launch abort system, as part of NASA's CCDev2 program will result in a preliminary design of all the upgrades necessary to convert the cargo Dragon spacecraft and Falcon 9 into a certified crew transportation system.

d. Critical Design Review-level Development

Each flight of the Falcon 9 and cargo Dragon to the ISS brings us one step closer to flying astronauts to the ISS. Each of these flights will demonstrate many of the common elements between the cargo vehicle and the crew vehicle. Ultimately, the Falcon 9 will be one hundred percent common as between the cargo and crew vehicles. Therefore, though there is much work ahead, SpaceX already is beyond a Critical Design Review (CDR) equivalent level of maturity—and even into the production phase—with respect to many aspects of the vehicle system. This includes the main propulsion systems, structures, thermal protection systems (including the Dragon heat shield), power generation systems, altitude control, on-orbit propulsion systems, thermal control systems and GNC systems.

Crew-related modifications that have yet to reach a CDR-equivalent level of maturity include the remaining work on the launch abort system. The most significant remaining milestones will be full-scale pad abort and max-drag abort flight tests. In addition, crew displays and controls, a voice communication system, cabin layout and seats, space suits, environmental control and life support systems, launch pad and control center modifications, final approach guidance and control and the docking system will need to be matured to a CDR-equivalent level. The most significant remaining technical milestones for these systems will be human-in-the-loop testing of the environmental control and life support systems and spacesuits as well as static and dynamic testing of the seats and other mechanisms.

Beyond the launch abort system and crew accommodations, SpaceX's efforts to transport crews aboard Dragon also require additional ground facilities and crew training equipment. These would support flight crew training for nominal, off-nominal and emergency conditions. Full-scale spacecraft mock-ups may be required for training. Launch Control and Mission Control teams will be certified as planned for other Falcon 9 and Dragon missions, including joint operations training with NASA Mission Control Center—Houston (MCC–H). The launch pad will also be modified to include gantry access for nominal ingress/egress and emergency egress of crew and pad support team.

e. SpaceX Falcon 9 / Dragon vs. Russian Soyuz

The Russian Soyuz is an unquestionably capable vehicle with significant flight heritage. Indeed, SpaceX has benefited from lessons learned from Soyuz operations and predecessor spacecraft. That said, we do not intend to duplicate the capabilities of Soyuz, but to improve upon them. Critically, the Dragon will have the capability to transport up to seven crew members to the ISS—four more astronauts than Soyuz. Further, the Dragon has the capability to carry additional unpressurized cargo to the ISS as well as the capability to return cargo from the ISS—areas in which the Soyuz is highly limited.

Additionally, the Dragon and Falcon 9 offer several safety improvements relative to the Soyuz, including:

- modern electronic control systems and computers;
- improved redundancy in the automatic control system;
- simpler and safer egress from the vehicle during an emergency on the launch pad;
- improved data displays for ascent and entry;
- capability for the crew to initiate an abort during the launch phase of the mission;
- capability for the crew to initiate the deploy of the landing parachutes;
- first stage engine out capability; and
- NASA insight into design, testing and production (NASA has limited insight to the Soyuz rocket design as well as limited access to the production facilities for the spacecraft and the rocket).

One of the largest safety distinctions between the Falcon 9 and Dragon system over the Soyuz transport system is the reduction in separation events—failure of separation events is one of the most common events leading to mission failures of space systems. The Soyuz launcher and spacecraft must release four side-mounted booster modules, the second stage, the third stage, the launch escape tower, fairing, propulsion module and habitation module prior to the point where the crew can enter safely in the Soyuz descent module. For the Dragon and Falcon 9, there are only four separation events which must occur prior to the Dragon's entry: separation

of the first stage, second stage, external cargo module or trunk and for a nominal mission separation of the nose fairing.

III. Commercial Crew Integrated Design Contract Proposal

NASA's recently issued draft request for proposals (DRFP) for the Commercial Crew Integrated Design Contract (CCIDC) has incorporated key features critical to facilitate successful commercial partnerships. SpaceX appreciates the fact that the contract will be firm fixed-price and milestone-based; includes cost sharing with fixed government investment; and waives cost and pricing data requirements inherent in certain Federal Acquisition Regulation (FAR) based contract formulations. SpaceX has offered NASA several suggestions to improve the DRFP and the subsequent contract implementation. Those suggestions focus on resolving certain key technical issues prior to contract award; focusing NASA approval authority with respect to design, development and test activities; placing a greater emphasis on development and test activities; and defining an insight plan that creates a teaming relationship between NASA and the contractor.

The DRFP indicates that several documents, including any proposed alternative technical standards, the integrated system baseline review (ISBR) and integrated critical design review (ICDR) plans, and the project management plan, are to be provided as drafts or initial documents at the time the proposal is submitted. All of these documents will have significant cost and schedule impacts and the technical standards will also drive the design of the vehicle. However, the final versions of these documents will not be approved until after the contract is signed. This timing makes it difficult to know exactly what commitments a contractor is making in its bid response. This concern can be easily addressed by having these key documents agreed to prior to signing the CCIDC contract.

SpaceX has found that the COTS and CRS public-private partnership approach with NASA combines and capitalizes on the strengths of both partners. The requirements in this DRFP have the potential to mitigate the proven benefits of this approach by exponentially increasing NASA's involvement in design, development and testing.

SpaceX has also suggested that insight personnel be teammates. According to the DRFP, the NASA insight team is to be given full access to the contractor's activities while being specifically precluded from providing any NASA resources (services, technical expertise, or access to Government property) to the contractor. As a result, the insight team is tasked to "audit and report" and thus becomes a second oversight team. Instead of an "audit and report" model, given successes witnessed under the interactions to date on the COTS and CRS programs, we propose that we work together as partners to a larger degree.

IV. The Commercial Space Market

At present, SpaceX has over forty flights on manifest, representing approximately $3.5 billion in revenues from the U.S. government, commercial and international business customers. NASA missions represent approximately 40 percent of those flights. Our ability to compete successfully in the domestic and international commercial market demonstrates the long-term viability of our business model and allows us to keep our costs to the U.S. taxpayer low.

SpaceX currently has the lowest launch prices in the world and, as noted by a Chinese government official earlier this year, even the Chinese do not believe they can beat them. Although our prices shatter the historical cost models of government-led developments, they are not arbitrary or premised on capturing a dominant share of the market, nor are they "teaser" rates meant to lure in an eager market only to be increased later. SpaceX's prices are based on known costs and a demonstrated track record and exemplify the potential of America's commercial space industry.

Critically, as the provider of an end-to-end solution for crewed missions, with our own manufacturing of the launcher and the spacecraft, and with the provision of all launch and recovery operations, SpaceX is uniquely positioned relative to competitors with respect to the impact of sales of commercial crew missions on the overall business. Each NASA purchase of our crewed capabilities complements our booster sales and production because the Falcon 9 will be the same for satellite carriage, cargo carriage, and ultimately crew carriage. Moreover, the commonality of features between our cargo Dragon and crewed Dragon likewise speaks to the economies of scale that we can achieve with spacecraft production and operations, maximizing efficiencies and driving down costs for the consumer. This is a key differentiator as between SpaceX and others when considering the commercial human spaceflight market.

However, as to the commercial human spaceflight market alone (taking into account the concept above that this market ties directly to the other well-known markets), NASA is the primary market driver for launching human beings into space. NASA is currently purchasing those services on the commercial market from Russia, the only currently available supplier. As a Nation, we are paying too a high price for those services—currently $56M per seat—due to the lack of competition and supply.

There is ample evidence of a demand for spaceflight beyond NASA, though it has yet to emerge as a substantial operational secondary market. In the past decade, seven individuals bought eight very expensive tickets to fly to the ISS on a Russian Soyuz. That may not seem like much, but even as prices dramatically increased since Dennis Tito first flew back in 2001, every seat available for sale has been sold. No tickets have been sold for the past two years because Russia is providing one hundred percent of their Soyuz capacity to serve the ISS partnerships. This evidence ratifies our view that offering seats for half or a third of the Soyuz price will expand the human spaceflight market. Moreover, alternative low-earth destinations such as the Bigelow space modules provide another strong market opportunity.

Non-spacefaring nations are also interested in space access. Between 1978 and 2010, ninety-six astronauts from thirty-one nations without indigenous spaceflight capabilities traveled into orbit.[3] According to NASA's Commercial Market Assessment, there is a desire among other countries "to send astronauts into space to perform scientific research, acquire technical knowledge, and increase national prestige."[4]

Further market potential also exists in the United States. The ISS is America's national laboratory in space and like all laboratories its productivity depends on how many scientists can visit the lab, conduct their experiments and return to their public or private enterprises. NASA currently bases astronauts at the ISS for six months. That limitation is based on how many Soyuz capsules are produced each year, how long the Soyuz is rated to last on orbit and the high price of Soyuz seats.

The ISS can actually support seven crew members once we have a better crew rescue capability. Commercial crew will deliver that capability. Should the U.S. space industry lower the cost to between $20 and $30 million per seat, it will be possible for research scientists to visit the ISS for shorter periods of time, conduct dedicated research and return to Earth. Less costly, more regular access to ISS will enable more scientists to do more research in the same amount of time, with the same amount of dollars.

Overall, SpaceX's business model is based on a diverse customer base that spans multiple markets. We have increased the U.S. share of the commercial space launch market since we started competing for and winning launches in 2008. For the first time in more than three decades, America last year began taking back international market-share in commercial satellite launch. Whereas in 1980, one-hundred percent of commercial launches took place from within the United States; last year, it was less than twelve percent. NASA's and SpaceX's efforts and investments are bringing critical launch revenue back to the U.S. and will bring thousands of jobs with it.

This remarkable turn-around was sparked by the investment NASA made in SpaceX in 2006 as part of COTS. By leveraging private funding with federal investment, controlling our costs and developing a diverse customer base, we are able to offer competitive pricing to our commercial and government customers. Safe, reliable and affordable transportation of cargo and astronauts to low Earth orbit by an American company will keep jobs in the United States; eliminate reliance on Russia to support the ISS; and providing significant taxpayer savings that instead can be invested in what NASA does best: pursuing the next frontier.

Mr. Chairman, I am honored by your invitation to provide testimony today. Through continued public-private partnerships like the one that helped develop the Falcon 9 and Dragon system, commercial companies will transform the way we access space. Together, government and the private sector can simultaneously increase the reliability, safety and frequency of space travel, while greatly reducing the costs.

NASA's Commercial Crew Development Program has the potential to be the most fiscally responsible means to rapidly advance American human spaceflight. To date, it has protected taxpayer dollars with fixed-price, pay-for-performance contracts. It has forced companies to compete on safety, reliability, capability and cost. And it leverages private investment—making taxpayer dollars go further.

Chairman HALL. Sir, I thank you.

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[3] NASA. *Commercial Market Assessment for Crew and Cargo Systems Pursuant to Section 403 of the NASA Authorization Act of 2010 (P.L. 111–267),* p.12, April 27, 2011.

[4] Ibid.

I now recognize our fourth witness on the panel, Mr. Charlie Precourt of ATK.

STATEMENT OF MR. CHARLES PRECOURT, VICE PRESIDENT, ATK LAUNCH SYSTEMS GROUP, BRIGHAM CITY, UTAH

Colonel PRECOURT. Chairman Hall, Ranking Member Johnson and Members of the Committee, thank you so much for allowing me to present our plans at ATK for commercial crew and our Liberty launch vehicle.

Liberty is a launch vehicle capable of lifting any of the crewed spacecraft that are currently under consideration with margin to the ISS orbit. We believe that Liberty is an innovative way to support the ISS because it leverages significant prior investments in NASA shuttle and Constellation programs as well as the European space agency's RN–5 launcher.

To give you an easier reference as to what makes up Liberty, I have a short video that lays out the system. Mr. Chairman, if you would allow me, I would share that video.

As you mentioned, Mr. Chairman, the recoupment of upfront investments is a significant factor for us, so we have chosen to use and leverage significant elements from both the space shuttle, as you see here, the booster forms the first stage of Liberty and the work that went into Constellation to provide the five-segment booster is going to be leveraged here as well. From Ariane, we chose the core element of that vehicle, which is a liquid hydrogen/liquid oxygen stage which matches very nicely in terms of performance and suitability to create the Liberty vehicle concept. The design, as I mentioned, can carry any of the spaceflight currently under consideration with margin. The vehicle has 44,500 pounds of performance to the space station's orbit.

The first-stage propulsion system benefits from many, many years of flight on the space shuttle, where we realized 221 successful flight operations, and the Constellation program was further evolved with improvements in materials, processing and increased safety. In the current configuration that you see here, this was the development motor test of the five-segment motor. It produces 3.7 million pounds of thrust. The upper stage is derived from the Ariane 5 vehicle, which is used by the European space agency to launch the cargo module, the ATV, to the ISS for the Europeans' contribution. Here is that stage being assembled in its vertical assembly building. It uses the Vulcain-2 engine, 46 consecutive successful flights. The Ariane-5 enjoys the lowest premiums for insurance of any launcher on the planet for commercial satellite operations.

Launch operations likewise will leverage activities at the Kennedy Space Center facilities that are already in place, again, minimizing the upfront investment for major elements. As a matter of fact, from a business case standpoint, the ongoing remaining investment has to do with the integration of the two elements so that they can fly together. We have made significant progress on the Liberty program over the past year and a half and are continuing under an unfunded Space Act agreement with NASA. Liberty was first proposed at a firm fixed price for NASA under their CCDev2 solicitation, and although NASA ultimately chose in that competi-

tion to fund only the spacecraft providers, we are very pleased and honored that NASA rated Liberty very high in both business and technical merits. Only two of the 18 proposals submitted were rated better.

The Liberty focuses foremost on achieving the maximum possible levels of safety for our astronauts. We believe Liberty is the safest, most cost-effective launch vehicle design available and is fully compliant with the recommendations of the Columbia Accident Investigation Board. One such recommendation was to lower the complexity of the launch vehicle and reduce the number of failure points. Liberty draws its safety rating from a simple design with an absolute minimum number of moving parts. A Valador study earlier this year showed that Liberty was more than 10 times safer than shuttle and even safer than the Ares I design because it uses established stages. The integrated vehicle today has passed its systems design review and is approaching preliminary design review. We are approximately one year to critical design review given adequate funding.

Challenges going forward include adequate funding as an adequate funding profile is required. In the case of Liberty, because it leverages flight-proven elements, much of the development is complete and the amount of necessary government funding is in fact quite modest. The infusion of outside capital is available to Liberty but awaits customer endorsement of the value proposition that Liberty presents. As a result, working on an unfunded Space Act agreement has slowed our milestone plans towards Liberty's first flight test.

Additionally, I offer a thought about strategy from an acquisition standpoint in the government-private industry partnerships. When NASA chose to fund only spaceflight in CCDev2, it placed a higher burden on the launch vehicle providers, and from a human rating standpoint, launcher development is more challenging than the spaceflight development because the preponderance of risk to the crew during launch, which must be mitigated, emanates from the launch vehicle. Therefore, we believe and suggest that in NASA's acquisition strategy, it would benefit significantly from a greater investment on the launcher side of the equation than has been made to date. The August failure of the Russian Soyuz launcher attempting to deliver progress cargo to the ISS serves to underscore this point.

Mr. Chairman, I would like to thank you and commend the Committee for your attention to safety in fielding the next-generation system. In the NASA Authorization Act, you asked that the certification requirements be at least equivalent to the requirements of crew transportation currently in use as well as adherent to any relevant recommendations of the Columbia Accident Investigation Board. As a former astronaut and Chief of the Astronaut Office who personally selected the crew of Columbia, I believe we are capable today of an order of magnitude improvement in spaceflight safety, and I am also confident that striving continuously to achieve the maximum possible levels of crew safety in our human spaceflight systems will pay the biggest dividends in the long run.

I truly appreciate the opportunity to introduce our Liberty system to you today. The system is available in the near term with

a test flight possible within three years. Liberty offers a great opportunity to foster the next level of cooperation between Europe and the United States while reinstating and sustaining our access to the ISS. I believe that Liberty is a cost-effective solution posed to ensure America's commercial crew program is safe, robust and enduring. Thank you so much.

[The prepared statement of Colonel Precourt follows:]

PREPARED STATEMENT OF MR. CHARLIE PRECOURT, VICE PRESIDENT, ATK LAUNCH SYSTEMS GROUP, BRIGHAM CITY, UT

Mr. Chairman, Members of the Committee:

Thank you for inviting me to discuss NASA's commercial crew program and, more specifically, ATK's Liberty Launch System. Allow me to begin with a detailed introduction to the Liberty Launch System, background about our international partner and our progress to date, followed by some challenges I believe Liberty and others in the commercial crew industry are facing.

ATK and EADS-Astrium developed the Liberty Launch System as part of a new commercial space transportation business in response to NASA's CCDev-2 competition. The launch vehicle focuses first and foremost on achieving the maximum possible safety levels for our astronauts. Liberty also focuses on the sustainment of the International Space Station by delivering the safest and most cost-effective transportation capability as quickly as possible following the retirement of the Space Shuttle. Liberty achieves these important goals by leveraging flight proven, human-rated launch elements developed by both NASA and ESA, in their respective Shuttle, Constellation and Ariane programs. Liberty also delivers on the U.S. policy goals of increased use of commercial systems and increased international collaboration, while leveraging the prior investments of both the United States and Europe.

Liberty is a simple, inherently safe, two-stage launch vehicle. Its first stage is the five-segment solid rocket booster derived from the Space Shuttle and Constellation programs. The upper stage is the core liquid engine stage used in ESA's Ariane 5 program. Having both stages based on existing, flying systems dramatically lowers the remaining development costs as there are only minimal changes necessary to integrate the stages to form Liberty. Both stages were designed from inception to NASA's human-rating requirements (Shuttle, Ares I and the Hermes Space Plane that was originally envisioned for launch of ESA's astronauts). This heritage enables unmatched crew safety. Liberty has a payload capacity of 44,500 pounds, which is enough to carry any of the currently proposed crew vehicles, with margin, to low Earth orbit. The launch vehicle will use existing facilities at NASA's Kennedy Space Center for processing and launch, including the Vehicle Assembly Building, mobile launch platform and launch pad, as well as the services of an expert NASA and contractor workforce across the country to perform design, testing, integration and launch operations.

The first stage's five-segment solid rocket booster enables Liberty to leverage the successes realized and data collected from close to 300 booster flights and tests. The five-segment booster takes advantage of new advances in materials and propellant design that provide even higher safety and performance than the original shuttle version. The five segment solid rocket has been successfully ground tested three times, and a flight test in a Liberty-like configuration (Ares I-X) has successfully demonstrated the operational concept and performance margins. These milestones have brought the first stage to a CDR-equivalent level of maturity. The booster has also recently been slated for use on the initial test flights of NASA's Space Launch System, which enables considerable synergy and cost-savings between the two programs.

Liberty's second stage has achieved 46 successful consecutive launches since 2003 as the core of the Ariane 5. As with the first stage, there is valuable synergy and cost savings with this propulsion element, as the Ariane 5 is ESA's prime vehicle for launching cargo resupply to the ISS via the Automated Transfer Vehicle (ATV). Astrium's track record of reliability is such that commercial payloads flown on the Ariane 5 are rewarded with the lowest insurance rates in the launch industry. The flight-proven liquid core stage includes the Vulcain-2 engine, a simple gas-generator engine that is inherently very safe and reliable and was designed to meet Human Rating Requirements – adding further simplicity, robustness and safety to the Liberty Launch System.

Both of Liberty's propulsion stages are at or beyond a CDR-equivalent level of maturity; however, since the two have not yet flown together, the *integrated* Liberty system is currently approaching a PDR-equivalent level of maturity. The development necessary to deliver the Liberty for commercial crew requires meeting two major milestones. These are the validation of design modifications that provide structural attachment of the two stages, and modifications enabling in-flight start of the upper stage (in the Ariane 5 configuration the Vulcain engine is ground-ignited). Current analysis shows these design milestones, with appropriate funding, can be completed and result in a full CDR-equivalent launch vehicle in less than one year.

We have made significant progress on the Liberty program over the past year and a half, culminating in an unfunded Space Act Agreement (SAA) with NASA's Commercial Crew Program Office in September, 2011. Analysis has determined that Liberty's capacity of 44,500 pounds of payload to low Earth orbit enables highly-competitive launch pricing. A full-vehicle

Systems Requirement Review and Systems Design Review were completed in early 2011. The team is currently working towards Preliminary Design Review, which is scheduled for early 2012.

Liberty's approach to meeting the goal of maximum achievable crew safety leverages numerous lessons from past programs. A major lesson articulated by the Columbia Accident Investigation Board was to lower the complexity of the launch vehicle to reduce the number of possible failure points. Liberty draws its high safety from a simple design with an absolute minimum number of "moving parts," which provides the lowest potential loss of crew. The resulting design is more than 10 times safer than shuttle and even safer than the Ares I vehicle projections, due to the use of established stages (Valador Study, April 2011). The use of the solid rocket first stage also provides a trajectory that enables survivable aborts throughout ascent to orbit, alleviating the black-out zones that are prevalent with full liquid launch vehicles. Liberty offers the safest, most reliable access to space of any of the launch vehicles currently proposed. The vehicle is also capable of carrying cargo or satellites and has payload capability comparable to that of the Delta IV heavy launch vehicle. The DoD has inquired about using the Liberty System as a new entrant into the EELV launch system and following their technical review, considered both first and second stages to be at a critical design review level of maturity – which ultimately allows Liberty to achieve operational flights at the earliest possible time.

A critical consideration for ATK was finding the right partner to speed development of a commercial crew capability. Leveraging existing systems not only minimizes cost to field a capability, but also results in achieving that capability soonest. The Ariane 5 core stage was the only one to meet all the desired attributes, which led to a natural partnership with EADS Astrium to create Liberty. Astrium brings demonstrated reliability, flight-proven mature hardware, and commercial know-how, all of which contribute to the reliability and faster development time of Liberty. With a European partner for the upper stage, the program also advances the *United States' 2010 National Space Policy*, which called for greater international partnerships for space exploration and takes advantage of the existing strong human space flight partnership between the United States and Europe.

An additional strength of the partnership is Astrium's long-term history and commitment to human space flight. Astrium is the prime contractor for ESA's Ariane 5 and the ATV cargo vehicle for the ISS. ESA is a historically very strong partner of NASA in the area of human

space flight. European astronauts have flown in NASA's Shuttle program under cooperative agreements since 1983, when the first non-American to fly on the Shuttle was German astronaut Ulf Merbold. Since then, Europeans have been part of 25 Shuttle missions, including nine Shuttle missions to the International Space Station. One ESA astronaut has also served as commander of an ISS crew that was comprised of Americans, Russians and Europeans. The Europeans have a significant investment in the International Space Station – nearly $10B, and place high priority on sustaining this commitment and ultimately achieving a strong scientific return from the ISS. ESA has contributed four of the ten modules that comprise the ISS—more than any other international partner, as well as supplying the ATV. In short, the Europeans have been close partners with the US for the entire history of both Shuttle and ISS. ATK's partnership with Astrium takes advantage of a partner highly motivated to the same objectives of high safety and robust ISS sustainment. The Liberty engineering team's completion of the System Requirements Review and System Design Review validates the Ariane 5 core stage mission suitability and enables Liberty to leverage ESA's prior investment of nearly $4 billion in Ariane's development. As Liberty represents Europe's greatest means of assurance of access to its own investment in the ISS, there is a high level of commitment to the success of the effort.

The Liberty program will sustain and create aerospace jobs in the U.S. In our arrangement with Astrium, Liberty's upper stage will be built using the existing manufacturing base. Once produced, it will be shipped to the Kennedy Space Center, where it will employ the services of hundreds of America's most highly-skilled aerospace workers and NASA's infrastructure to assemble and launch. Liberty has already created jobs in Utah, Florida, Ohio, Texas and Alabama, and additional jobs will be created across the country as our Liberty teams work with other NASA centers and suppliers.

Liberty was first proposed at a firm-fixed price for NASA's CCDev-2 solicitation. Had ATK received a funded SAA from NASA, Liberty's first test flight was slated for 2013 with its first crew launch on its third flight in 2015. Although NASA chose to fund only spacecraft providers, we were very pleased that NASA rated Liberty highest of all launch vehicles with high-confidence of success in both business and technical merits—only two of the 18 proposals submitted were rated better. Following the signing of the unfunded SAA in September, NASA assigned individuals based out of Kennedy Space Center and Marshall Space Flight Center to the Liberty team.

Our activities within NASA's unfunded Space Act Agreement further validate our technical approach and business model as sound options for ensuring commercial crew success; however, without partial funding from the government it is extremely challenging to recruit investors and close the business case. NASA's Commercial Orbital Transportation Services program demonstrated that providing "seed" money to stimulate commercial space entrants was effective. With this seed money it becomes the commercial space company's responsibility to execute the program both from a technical and business perspective. After commercially developing the basic space transportation system, it is appropriate for the government to acquire these services through a full and open competition.

Technical issues in development and testing of the Liberty vehicle are less of a challenge than achieving the optimum funding profile to complete development. The infusion of outside capital, although available, awaits customer commitment and endorsement of the value proposition. In the case of Liberty, because much of the development is complete, leveraging flight-proven elements, the amount of necessary government investment is quite modest. In fact, Liberty's CCDev-2 funding request was much lower than the awarded SAAs. As a result, NASA's strategy to emphasize spacecraft development in CCDev-2 has slowed our progress towards Liberty's first flight test.

An additional risk in fielding a commercial crew system is the remaining unknowns in NASA's certification process. NASA has drawn a distinction between human *rating* and human flight *certification*. Although Liberty is designed as a human rated system, NASA has not yet announced its final requirements for the commercial crew certification process. The degree of testing and verification required to achieve certification is still under development at the agency. This could ultimately affect a schedule delay, causing a larger gap in America's access to space and jeopardizing the success of the program. Some parallel funding of the launch vehicles being proposed for crew transportation would be appropriate to mitigate the possibility of surprises in certification. Any delay in the timeline for delivering commercial crew capabilities, given the limited life of the International Space Station, affects the business case for every commercial crew provider.

Liberty considered the commercial crew market potential in establishing our business model. Our assumptions did not depend on a significant initial market for non-US government astronauts. We do believe there are sovereign nations who, although cannot afford their own

space program, could and would fund citizen participants on a commercial system. This market will take considerable time to mature. Liberty, as a launch vehicle, will instead rely on cargo, science payloads and other large satellite opportunities such as with the DoD, in addition to commercial crew for NASA. Launch vehicles having the ability to serve these other markets are less sensitive to the commercial crew market size than are spacecraft uniquely designed to carry crew.

The NASA acquisition strategy of soliciting a full end-to-end service for commercial crew tends to stovepipe the design solutions offered, and does not facilitate interoperability. Interoperability is one of the major enablers for commercial success in the launch vehicle business. That is, a launcher should, through use of common interfaces, be able to fly multiple cargos with low recurring integration expense. Similarly, to enable a robust sustainment of the ISS, interoperability between launchers and spacecraft should be encouraged. Common interfaces will be difficult to achieve with an acquisition strategy that seeks offerings of an end-to-end service. As an alternative, NASA could leverage some acquisition aspects of their existing NASA Launch Services (NLS) program, which has the ability to consider more than one launcher for a given payload. This kind of robustness would largely mitigate the potential risk of abandoning ISS as recently was confronted with the Soyuz failure.

There has been some debate over the contracting mechanism of an SAA versus a Federal Acquisition Regulation (FAR) type contract for future commercial crew activities. However, focusing on a choice between SAA and FAR misses the point, as the objective is to facilitate the most cost-effective government contractor interface. NASA will need the commercially-developed vehicles and services to be certified to the agency's Human Rating requirements, which will require appropriate oversight with the design and development of these vehicles and services. In order to impose these requirements, NASA is naturally driven to a FAR procurement model rather than an "other-transactional-authority" such as an SAA. As a contractor very familiar with FAR-based contracts, we had concerns with how NASA was going to be able to administer that type of contract without over-burdening commercial companies and driving costs higher. However, we believe NASA is achieving the right balance with their approach to the Integrated Design Contract (IDC) phase of the Commercial Crew Program.

NASA's recent IDC requests for information have demonstrated that the agency has structured the procurement to accommodate commercial aspects of the acquisition while

maintaining appropriate regulatory compliance. NASA has carefully selected specific clauses from the FAR that will enable streamlined development while also providing appropriate protections for both the contractor and tax payer, which are not available through a SAA. NASA structured the acquisition as a competitive Firm Fixed Price procurement to eliminate the burdens associated with providing Certified Cost and Pricing data and complying with government-imposed Cost Accounting Standards. In addition, NASA has structured the approach to Rights in Data to enable potential providers to retain ownership and control of their Intellectual Property while still providing NASA insight. The agency also provides potential providers the opportunity to define the insight/oversight model associated with implementing and complying with NASA's Crew Transportation Plan. The Liberty team believes NASA's transition to this modified FAR-based procurement approach to commercial crew is appropriate. It provides adequate flexibility to enable progress while also performing the most critical functions of FAR contracts—protecting tax dollars, guaranteeing contractor performance, and providing greater assurance of the safety of the commercial crew systems.

An additional risk to the future of the ISS will be the continuing business viability of NASA's commercial partners. Given the significant investment in the ISS, including that of our international partners, NASA should ensure through its contractual arrangements that the ISS mission priority is assured. In addition to contractual means to establish appropriate priorities, the agency should seek to maximize collaboration and synergy between the commercial crew program and its other significant human space flight endeavor, the development of the Space Launch System and Multi-Purpose Crew Vehicle. People, facilities and hardware must be leveraged across both programs to realize the most cost-effective human space flight capabilities for missions in and beyond low Earth orbit. Both programs are critical for sustaining U.S. human spaceflight leadership. It was with this thinking in mind that Liberty was developed. It exploits people, facilities and hardware that facilitate both programs.

I would like to reemphasize our goal in commercial crew should be to deliver the maximum possible level of crew safety. Our knowledge and technologies today enable an order of magnitude improvement over Shuttle. The August 2011 failure of the Russian Soyuz launcher, attempting to deliver Progress cargo to the ISS, serves to underscore both the difficulty of space flight and the importance of focusing risk mitigation investments on our launch vehicles. By choosing to fund only spacecraft for the CCDev-2 portion of the development

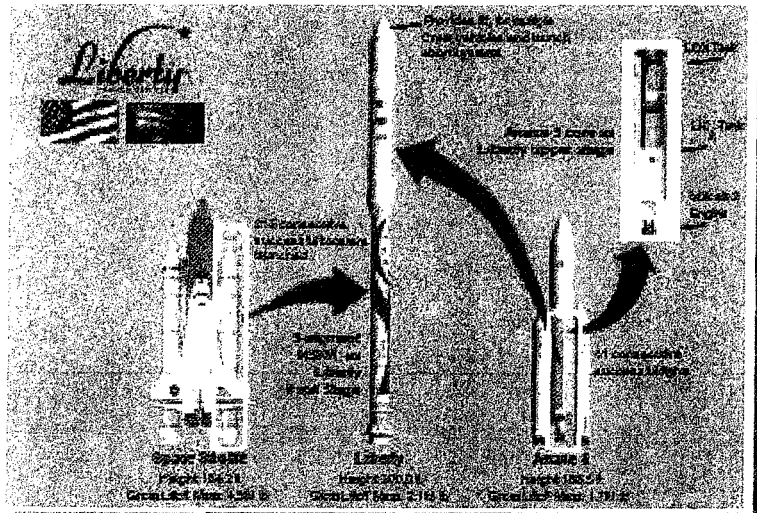
program, NASA has placed a higher obstacle before the launch vehicle providers. From a human rating and flight safety standpoint, the launcher development is significantly more challenging technically than the spacecraft. This is because the preponderance of risks to the crew during launch, which must be mitigated, emanate from the launch vehicle. The U.S. has not certified a human spaceflight launch vehicle other than the space shuttle in three decades. This is not only an issue for our company, but for all of those involved with commercial crew. Whether one is developing a launch vehicle or a capsule, the entire system must be successful for any one element to succeed. Given the nature of the challenge before us, NASA's commercial crew acquisition strategy merits a greater investment in the launcher side of the next generation system than has been made to date. Taking a near term lesson from the failure of the Soyuz rocket, and during this time of dramatic change for this country's human space flight program, we need to be extremely careful as a nation not to fall into the trap of taking shortcuts or overlooking requirements in hopes of shortening development time. As a former astronaut and Chief of the Astronaut Office who personally hand-picked the crew of Columbia, I am confident that striving continuously to achieve the maximum possible levels of crew safety in our human space flight systems will pay the biggest dividends in the long run.

I appreciate the opportunity to introduce our Liberty Launch System to you. The system is available in the near term, with a test flight possible within three years. Liberty offers a great opportunity to foster the next level of cooperation between Europe and the United States, while reinstating and sustaining our access to ISS. I believe our vehicle is a safe, reliable and cost-effective commercial crew launch solution poised to ensure America's Commercial Crew program is safe, robust and enduring.

Two Attach:
One Page Summary
Liberty Pictorial

The Liberty Launch System

ATK



ATK and Arianespace are developing the Liberty™ launch system as part of a new international commercial space transportation business. Liberty's availability can be accelerated by CEO Exploration funding

- Flight-proven human-rated hardware – better than [illegible] assent [illegible]
- 44,000 pounds into low earth orbit (LEO)
- Most suitable short trajectory
- Ability to launch all crew spacecraft currently in development
- The potential for first test flight in 2012
- Initial crew operational capability (IOC) in 2015
- Cargo capability by 2016
- Highly competitive unit cost

The Liberty Vehicle Offers:

- Safest, most reliable launch vehicle
  - Heritage design and experience
  - Existing stages – minimal remaining developments
  - Designed for human rating (Shuttle and Hermes programs)
  - Absolute minimum "moving parts"
- International cooperation – advances US national space policy
- Commercial approach to acquisition – Lowest cost to government, advances US national space policy
- Maximum leverage of existing NASA and ESA investments – multi $B from Shuttle, Ariane 5, and Constellation
- Maximum utilization of existing NASA KSC & MSFC assets and infrastructure
- Strong business case – best value for our space program, low remaining development cost jumpstarts the business
- Synergistic with NASA's Heavy Lift planned investments – both programs benefit by using common infrastructure

Chairman HALL. And we thank you.

I now recognize our, it says here final witness. I don't like the word "final" at my age. I will just say we will recognize the fifth witness of the first panel, Dr. George Sowers, to present his testimony.

STATEMENT OF DR. GEORGE SOWERS, VICE PRESIDENT, UNITED LAUNCH ALLIANCE, ENGLEWOOD, COLORADO

Dr. SOWERS. Mr. Chairman and Members of the Committee, thank you for the opportunity to appear today to discuss NASA'S Commercial Crew Program. My name is George Sowers and I am the Vice President of United Launch Alliance. I don't have a video but I have spent my career designing, developing, building and launching rockets and was the Chief System Engineer for the Atlas V development.

The formation of the United Launch Alliance in 2006 brought together the launch industry's two most experienced and successful launch vehicle teams and two of its most dependable launch vehicles families, the Atlas and the Delta. Our history spans over 1,300 successful space launches including the launch of John Glenn, the first American to orbit the earth.

Since formation, we have conducted 54 launches, almost one a month, with 100 percent mission success. We are entrusted with delivering the Nation's most critical payloads to support the war fighter, the intelligence community and national decision makers. Within the last year, we successfully completed the most ambitious launch campaign in the history of the National Reconnaissance Office, putting up five nearly priceless satellites in seven months. We are currently in the midst of an unprecedented launch campaign of five NASA science missions in six months. So far we have successfully launched the Aquarius spacecraft, the Juno spacecraft to Jupiter, and the Grail spacecraft to the moon. Within the next week, we will launch the NPOESS Preparatory Project and we will finish up the year with the launch of NASA's Mars Science Lab, an SUV-sized rover powered by a nuclear battery that may discover the first signs of life on that planet.

United Launch Alliance strongly supports Congress's and NASA's efforts to develop a commercial crew capability. In my mind, there are three main reasons for the Nation to invest in commercial crew and together they form a compelling argument.

First, the Nation needs this capability. Now that the shuttle is retired, our Nation is wholly dependent on the Russians to transport our own crews to and from the ISS. Currently, the government of Russia is NASA's sixth largest contractor receiving over $350 million per year. The recent Soyuz failure reminds us that the very existence of the ISS is now in jeopardy and that we are reliant on a single, fragile lifeline that we have little insight into or control over.

Second, the private sector has the expertise to provide safe and affordable crew transportation. The private sector can bring efficiencies and development and operations spurred by competition unobtainable in a government-owned and -operated system. In ULA's case, NASA can take advantage of the investments we have

already made, the rockets that are already flying in synergy with other users of our rockets like the DOD and NASA science.

The third reason is to stimulate and to promote commercial human spaceflight. As an example, my good friend, Bob Bigelow, is a visionary with a dream of a fleet of private space stations, but Bob needs a safe and affordable transportation system. NASA is in a unique position to create a transportation system that can address the Nation's needs while also providing opportunities for American entrepreneurs like Bob. NASA shouldn't count on this new market but will benefit substantially if it does develop.

Through NASA's investments in the Commercial Crew Development Program, the private sector is making great progress in developing a crew delivery capability. United Launch Alliance is proud to have been chosen by three of the four CCDev contractors, Sierra Nevada, Blue Origin and Boeing, to provide launch services using the Atlas V launch system. The Atlas program as a whole has a record of 98 consecutive successes, the best in the world. The Atlas V has launched 27 times with 100 percent mission success. It is the only rocket in its class certified by NASA to launch category 3 missions such as Juno and the Mars Science Lab, and it is the only rocket in the world certified to launch nuclear payloads.

The next step for Atlas is to launch humans. If NASA's Commercial Crew Program is to be successful, every effort must be undertaken to ensure the highest possible level of safety and reliability. Under an unfunded Space Act agreement with NASA, we are conducting a comprehensive assessment of the Atlas design against NASA's stringent human certification requirements. This entails a part-by-part, system-by-system review of the design, analysis and test pedigree of the Atlas.

We are also making excellent progress on the relatively few modifications required to accommodate human launch. These include the development of the emergency detection system that will provide a signal to the spacecraft to abort if a launch vehicle failure is imminent.

Looking to the future, we believe NASA's recently announced plans for the Commercial Crew Integrated Development Contract strikes the right balance between a commercial approach to delivering innovation and affordability and the appropriate level of certification and oversight necessary to ensure safety. The importance of insight and rigorous certification has been highlighted by the recent Soyuz failure. For new, unproven vehicles, this rigor is mandatory in addition to establishing a track record of demonstrated and repeatable success. With adequate funding, Atlas could be ready to support test flights in 2014 and operational flights in 2015.

In conclusion, we strongly believe NASA's commercial crew program is vital to extend our Nation's leadership in human spaceflight. American industry represented by the companies here today has the expertise and experience to create safe and affordable crew access to the ISS and potentially stimulate an entire new economic sector.

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

[The prepared statement of Mr. Sowers follows:]

PREPARED STATEMENT OF DR. GEORGE SOWERS, VICE PRESIDENT, UNITED LAUNCH ALLIANCE, ENGLEWOOD, CO

Mr. Chairman and Members of the Committee, thank you for the opportunity to appear today to discuss NASA's Commercial Crew Program. My name is George Sowers and I am the Vice President of Business Development and Advanced Programs for United Launch Alliance. I was educated as a physicist but have spent my career designing, developing, building and launching rockets. I was the chief systems engineer for the development of the Atlas V rocket.

Introduction

My company, the United Launch Alliance, LLC was formed in 2006. ULA's heritage reaches back 50 years to the beginnings of the space age and human spaceflight. The formation of ULA brought together the launch industry's two most experienced and successful launch vehicle teams and two of its most dependable launch vehicle families, the Atlas and the Delta. Our history spans over 1300 successful space launches including historic achievements as a part of the nation's first two human spaceflight programs, Mercury and Gemini. At the height of the space race, it was an Atlas rocket that launched John Glenn into orbit and America into a proud space future. Since then, we've delivered payloads with unprecedented reliability and unparalleled performance—helping America become the world's leading space-faring nation.

Our current customers are the Department of Defense, the National Reconnaissance Office, NASA, and commercial satellite system providers. ULA was formed to provide the highest reliability launch services to these customers while lowering cost through the consolidation of infrastructure.

Since its formation nearly five years ago, ULA has conducted 54 launches, almost one a month, with 100% mission success. ULA is entrusted with safely delivering the nation's most critical missions to support the warfighter, the intelligence community and national decision makers. Within the last year, we successfully completed the most ambitious launch campaign in the history of the National Reconnaissance Office, putting up five nearly priceless, irreplaceable satellites in seven months. ULA has proven it can reliably deliver critical missions safely and on schedule. Schedule reliability is also critical for many missions and each of the dozen missions performed by ULA in the last year has occurred within a day or two of its planned launch date.

The evidence of ULA's success is literally on orbit. Every GPS satellite, every missile warning satellite, nearly every intelligence collection satellite, weather satellite, and military communications satellite and nearly every major NASA science mission has been launched-successfully-on a ULA or ULA heritage product. As a result, America has been able to push the frontiers of innovation and discovery; has the most capable spy satellites in the world; has the best satellite navigation system ever imagined; and has more rovers on, and more spacecraft orbiting distant planets than anyone else.

We are currently in the midst of an unprecedented launch campaign for NASA's science program. So far, ULA has successfully completed three of five planned missions, including the launch of the Juno spacecraft to the planet Jupiter in August and the launch of the Grail spacecraft to the moon in September. Our next launch in the campaign occurs within the next week with the launch of the NPOESS Preparatory Project (NPP), a precursor to the next generation weather satellite. We'll finish up the year with the launch of NASA's Mars Science Laboratory, an SUV sized rover powered by a nuclear battery that may discover the first signs of life on another planet.

ULA's rockets are the most reliable in the world and we're routinely tasked with launching the most challenging missions imaginable. Five years ago, the fastest object ever created by man, the Pluto New Horizons spacecraft, was launched on an Atlas. Two years ago, we worked with NASA to guide a Centaur upperstage into the moon, proving that there was indeed water hidden in its deep craters. The missions performed by the Delta IV heavy, the nation's most capable launch vehicle, are incredibly complex, but classified. We are currently working with NASA to potentially use the Delta IV heavy to launch the Orion spacecraft on its first uncrewed test flight.

Why Commercial Crew?

I'd like to start by commending this committee for having the foresight and vision in its 2008 NASA Authorization Act to help spur a commercial crew capability for the International Space Station, and its subsequent support in the 2010 NASA Au-

thorization bill. Nearly 50 years after Glenn's first flight, these efforts are helping unleash a new space race-this time it's an all-American space race to help us further unlock the boundless possibilities of the space frontier.

ULA strongly supports both Congress' and NASA's efforts to develop a commercial capability to meet U.S. obligations to deliver crew to and from the International Space Station. In my mind, there are three main reasons for the nation to invest in commercial crew and together they form a compelling argument.

First, the nation needs this vital capability. Now that the shuttle is retired, our nation is wholly dependent on the Russians to transport our own crews to and from the ISS. Currently, the Government of Russia is NASA's sixth largest contractor, receiving over $350M per year. Not only does this represent thousands of high tech jobs sent overseas, but it's ceding our leadership as a space-faring nation. Furthermore, the Russian Soyuz vehicle now represents the only means to send crew to the station. The recent failure of that normally reliable craft reminds us that the very existence of the ISS is now in jeopardy, and that we are reliant on a single fragile lifeline that we have little insight into or control over.

We should have an urgency to get a commercial service up and operating as quickly as possible to close the Human Spaceflight "Gap." I have no doubt that the U.S. aerospace industry (represented by the companies here today) is up to the task. We have the ingenuity and the inventiveness necessary to meet this national imperative.

The second reason the U.S. Government should invest in commercial crew is that the private sector has the expertise to provide crew transportation safely and can provide the best value to the taxpayer. The companies competing for the commercial crew service include those with decades of experience in NASA's human spaceflight program, such as Boeing. Newer companies bring fresh ideas and the entrepreneurial spirit like Sierra Nevada, Blue Origin and SpaceX. The private sector already possesses the world's most reliable rocket with the Atlas V.

Affordability is maximized by several factors. Specifically, the private sector can bring efficiencies in development and operations, spurred by competition, unobtainable in a government owned and operated system. In ULA's case, the government can take advantage of the billions we and the Air Force have already invested and the synergy and cost sharing with other users of those rockets like the DOD, NRO, NASA science and commercial companies.

The third reason the U.S. Government should invest in commercial crew is to stimulate and promote commercial human spaceflight-a policy consistently supported by numerous Congresses and Administrations, including in the NASA Authorization Act of 2010 and the most recent National Space Policy. We believe this is the right policy and that free and competitive markets create the most efficient conditions for promoting economic development.

As an example, my good friend Bob Bigelow is a visionary with a dream of a fleet of private space stations. His customer base will be countries that want a space program but cannot buy or beg time on the ISS. But Bob needs a safe and affordable transportation system to orbit. NASA is in a unique position to create a transportation system that can address the nation's needs for access to ISS, while also providing an opportunity to unleash the power of the U.S. entrepreneur in Low Earth Orbit.

We don't know if ideas like Bob Bigelow's are viable. There is extremely high uncertainty in this market and NASA shouldn't build its program assuming it materializes. But if a market does emerge, everyone will benefit: new jobs will be created and the Government's prices will go even lower, across both the civil and military sectors.

ULA support to Commercial Crew

Through NASA's investments in the Commercial Crew Development (CCDev) program, the private industry is making great progress in developing a crew delivery capability. ULA is proud to have been chosen by three of the four CCDev contractors (Sierra-Nevada, Blue Origin and Boeing) to provide launch services using the Atlas V launch system. We and our customers believe the Atlas V is the right launch vehicle to help establish commercial human spaceflight. From its roots as the launch vehicle for the manned Mercury program in the 1960s, each new generation of the Atlas system has demonstrated advancements in reliability and performance. The Atlas program has a record of 98 consecutive successes, best in the world. Today's Atlas V is the culmination of decades of improvements and lessons learned. The Atlas V has launched 27 times with 100% success. A list of those launches is included in Table 1. It is the only rocket certified by NASA to launch Category 3 missions, a category reserved for NASA's most important science missions, like Juno

and the upcoming Mars Science Laboratory. It is the only rocket in the world certified to launch nuclear payloads to orbit, and it's entrusted to launch many of our nation's most critical national security missions.

The next step for Atlas is to launch humans. If NASA's commercial crew program is to be successful, every effort must be undertaken to ensure the highest possible level of safety and reliability. A key element of this is the rigorous process of human system certification. Under a Space Act Agreement with NASA, we are conducting a comprehensive assessment of the Atlas design against NASA's stringent human certification requirements. This entails a part-by-part, system-by-system review of the design, analysis and test pedigree of the Atlas. We are also performing a detailed analysis of the hazards faced by the crew and their mitigation as well as a Probabilistic Risk Assessment for the launch of crew. My expectation is that the Atlas will fare very well. This is because of the rigor and attention to detail we applied during the original design and development process as well as the flight demonstrated performance of the system through 27 successful missions.

We are also making excellent progress on the relatively few modifications to the Atlas required to accommodate human launch. These include the development of the emergency detection system (EDS), a health monitoring system that will provide a signal to the spacecraft to abort if a launch vehicle failure is imminent. A prototype of this system was demonstrated last year in our high fidelity systems integration lab, correctly detecting a wide range of potential failures and sending the abort signal in time to ensure a safe abort. We are progressing on the design of the modifications required at the launch pad to accommodate getting crew into and out of the spacecraft. And we're working with several spacecraft providers on the details to integrate their systems to the Atlas.

Looking to the future, we believe NASA's recently announced plans for the Commercial Crew Integrated Development Contract (CCIDC) strikes the right balance between a commercial approach delivering innovation and affordability and the appropriate level of certification and oversight necessary to ensure safety. The importance of insight and rigorous certification criteria has been highlighted by the recent Soyuz failure. For new, unproven vehicles, you need the rigor even more, in addition to establishing a track record of demonstrated and repeatable success.

With adequate funding, Atlas could be ready to support test flights in 2014 and operational flights in 2015.

Conclusion

In conclusion, we strongly believe NASA's commercial crew program is vital to maintain our nation's leadership in human spaceflight. The U.S. private sector has the expertise and experience to create safe and affordable crew access to the ISS and potentially stimulate an entire new economic sector with thousands of high tech jobs. Affordability is greatly enhanced by the use of Atlas which leverages synergy with the DOD, NRO, NASA Science and other users. With adequate funding, we can be ready to launch crew within three to four years.

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

Table 1. Atlas V Launch History

DATE	CONFIGURATION	MISSION	CUSTOMER
21 Aug 2002	Atlas V 401	Hotbird-6	Eutelsat
13 May 2003	Atlas V 401	Hellas-Sat-2	Hellas-Sat
17 July 2003	Atlas V 521	Rainbow I	Echostar
17 Dec 2004	Atlas V 521	AMC-16	SES Americom
11 Mar 2005	Atlas V 431	Inmarsat 4 F-1	Inmarsat
12 Aug 2005	Atlas V 401	MRO	NASA
19 Jan 2006	Atlas V 551	New Horizons	NASA
20 Apr 2006	Atlas V 411	Astra-1KR	SES Astra
8 Mar 2007	Atlas V 401	STP-1	USAF
15 Jun 2007	Atlas V 401	NROL-30	NRO
10 Oct 2007	Atlas V 421	WGS-1	USAF
10 Dec 2007	Atlas V 401	NROL-24	NRO
13 Mar 2008	Atlas V 411	NROL-28	NRO
14 Apr 2008	Atlas V 421	ICO G1	ICO Global Communications
3 Apr 2009	Atlas V 421	WGS-2	USAF
18 Jun 2009	Atlas V 401	LRO/LCROSS	NASA
8 Sept 2009	Atlas V 401	PAN	Lockheed Martin
18 Oct 2009	Atlas V 401	DMSP F-18	USAF
23 Nov 2009	Atlas V 431	Intelsat-14	Intelsat
11 Feb 2010	Atlas V 401	SDO	NASA
22 Apr 2010	Atlas V 501	OTV-1	USAF
14 Aug 2010	Atlas V 531	AEHF-1	USAF
20 Sept 2010	Atlas V 501	NROL-41	NRO
5 Mar 2011	Atlas V 501	OTV-2	USAF
14 Apr 2011	Atlas V 411	NROL-34	NRO
7 May 2011	Atlas V 401	SBIRS Geo-1	USAF
5 Aug 2011	Atlas V 551	Juno	NASA

Chairman HALL. And I thank you, and I thank all of you for your testimony. Reminding Members that Committee rules limit questions to five minutes. We will try to stay as close to that five minutes as we can, and the Chair at this point will open the round of questions. The Chair recognizes himself for five minutes.

As I mentioned in my opening statement, some of us remain very concerned that the promise of commercial markets could put the government in the position of supporting or bailing out companies in order to preserve a national capability, and I hope we are wrong in this fear, and I hope we will hear more from NASA on the next panel. But my questions to all the companies on this panel are, and these are to each of you and probably I will start with Mr. Elbon of Boeing, what are the non-NASA commercial crew markets that you intend to serve and what is your company's business case if there are no customers other than NASA?

Mr. ELBON. Thank you, Mr. Chairman. As I mentioned in my testimony, we are basing our business case, structuring our business case so that it can close if all we do is transport NASA crew to the space station.

Chairman HALL. And in your statement, does your company have the financial backing to see this development program to a conclusion? That is very important. I would like for you to give us all the explanation you can on that.

Mr. ELBON. Okay, sir.

Chairman HALL. Quickly.

Mr. ELBON. Okay. So Boeing has a history of executing several X Prize programs for the government. Often it takes company investment to complete those but we have a track record of moving into fixed price kinds of contracting and then completing those contracts. That will be no different for commercial crew. We of course are laying in a very good program plan, one that we believe can be executed for the funding that we propose and that will be available. But our track record of executing on those I think speaks for itself.

Chairman HALL. All right. Mr. Lindsey?

Colonel LINDSEY. Yes. For our business case in terms of closing, we too think we can close, even if NASA is our only business. I think that the challenge will be getting there in a timely fashion based on the funding that we have, but that is what we are proposing.

But let me expand a little bit on the market beyond NASA because that is the question you asked, sir, and the areas that we think that we have another markets is in cargo transportation, potentially orbital servicing with our vehicle because of its unique capabilities and additional ability to maneuver in orbit, potentially orbit sensor and test bid operations, and we talk about other businesses, other business areas besides NASA. We think there may be other civil agencies involved. There is some tourism involved, potentially military agencies, DOD.

One thing I wanted to expand on was international markets. The Russians in their flying participants or tourists on the Soyuz actually flew a crew member from both South Korea and Malaysia, so we think there is potential that other nations would want to fly into space. Right now, the International Space Station partnership

is limited to the founding partners and the crew slots on the space station are based on your contribution to the development and the building of the space station. But in the future we think there is a possibility that you could open up the International Space Station to additional international partners with additional capabilities.

Chairman HALL. All right. Mr. Musk.

Mr. MUSK. So I will address that in a couple of ways. With respect to the launch vehicle, as I mentioned earlier, we have other 35 launches under contract. In fact, for the last few years SpaceX has won more launch contracts than any other company in the world, in fact, any other country in the world. So I believe that the costs associated with the launch vehicle, the rocket part, is well taken care of.

Then with respect to the spacecraft, we are slated already to provide more cargo servicing missions to the space station than any other organization. And since our cargo and crew vehicle are essentially the same, it means that the cost of crew is divided over all of those missions and so it results in a great deal of efficiency and a great deal of reliability.

And then thirdly, I will put it in the Congressional Record, I will personally guarantee this.

Chairman HALL. Mr. Precourt.

Colonel PRECOURT. Mr. Chairman, as a launch vehicle provider, we don't have a lot of the same challenges that the crewed spacecraft do from a business case standpoint. We are addressing a number of opportunities that customers could leverage Liberty. We are gearing it toward commercial crew because that is the most difficult design part of a launch vehicle. Once it has that capability, it can serve other customers. I would like to point out NASA's NLS, NASA Launch Services, system that has been in place very successfully for many years, launches deep space probes, payloads, science platforms. Those are missions of interest that Liberty could certainly service as well as other missions for other government agencies in the satellite and payload interest areas, leveraging the capabilities and performance of a vehicle designed for crew. Crew and cargo, other science missions and other government agency payloads really give you the leverage you need there, and we would be designing a common interface that could handle multiple users of the launch vehicle.

Chairman HALL. And I thank you.

Dr. Sowers.

Dr. SOWERS. Yes. We are a little bit different than some of the other companies up here. Our investment is already substantially made. Our rockets are flying today. The Atlas V that has been chosen by Boeing, Sierra Nevada and Blue Origin has already had 27 successful flights. We have an ongoing business of roughly six to eight missions per year consisting of DOD, National Reconnaissance Office, NASA science and commercial customers, and commercial crew would be merely adding one to two missions a year into that already robust manifest and so our business case does not count on other customers. We have been working with Bob Bigelow for a number of years and so we are optimistic about a new market but also my company lived through the EELV experience where we made assumptions about a commercial market that didn't mate-

rialize and so that scar tissue is very fresh and tender in our memories.

Chairman HALL. And we thank you, and my time has expired by almost a minute.

At this time I recognize Mrs. Johnson.

Ms. JOHNSON. Thank you very much. I have listened very attentively and I am very excited about this possibility. What I would like each of you to comment on is whether or not you think Congress is justified in making this initiative at this time, and what realistically do you expect of the U.S. government? And thirdly, where are your potential markets for now? I want to make sure I make efficent use of my time, if you will start, Mr. Elbon.

Mr. ELBON. I think it is very important that commercial crew exists as part of an enabling system to provide low-cost transportation to ISS, affordable transportation, in such a manner that there is funding left over in NASA's budget so that we can invest in capabilities for exploration beyond low Earth orbit. So I think that investment is prudent at this time.

You asked about other markets, I believe. We believe there are—as others have said, there are certainly—it has been demonstrated that there are individuals that would pay to fly to station but there is also, through the opportunities that Mr. Bigelow is putting in place, other countries in the world that would like to have their own space program, can't afford the infrastructure associated with that and so that business model I think has a really good opportunity of maturing and becoming an additionally commerce in low Earth orbit that can be served by commercial crew transportation.

Chairman HALL. Go ahead, Ms. Johnson.

Ms. JOHNSON. I was waiting for Mr. Lindsey.

Colonel LINDSEY. Yes, Congresswoman. The reason I think we need to be back in the business of commercial crew, I think—as I mentioned in my remarks, low Earth orbit access to me is a vital interest to this country. When we retired the shuttle, we are in a gap period where we don't have that access and we are relying on the Russians and spending, as you mentioned earlier, $450 million a year paying the Russians to provide that service. I think it is very important that we get back into that business and establish our preeminence in space. So that is probably my primary reason. That is why I am doing what I am doing and why I think it is really important.

In terms of the markets that you asked us about, as John mentioned, there are some commercial individuals that could afford to do that. I think our bigger market, though, is potentially with other governments, going to the International Space Station. We know for a fact that there is interest in doing that for other nations, not just International Space Station partners, and there is, we think, there is interest in doing other sorts of mission with our vehicle like satellite servicing and things like that like we have done in the past with space shuttle.

Mr. MUSK. As I mentioned, with respect to the rockets, those costs, those are a given. So then with respect to the cargo version of the spacecraft, those costs are also given because we are already doing that for NASA, so we have a high certainty associated with those so it is really what is incremental to carry crew, and we an-

ticipate that that is perhaps no more than about a 20 percent increment to carry crew, primarily related to the launch escape system and improved life support systems. And in fact, again, I am willing to go on record and say that at a launch rate of four crewed flights per year, we are willing to commit in current-year dollars to $140 million per fight with a seven-astronaut contingent so that would mean $20 million per astronaut and compares very favorably with what we are currently paying the Russians, which is $63 million per astronaut. So you have it on record.

Colonel PRECOURT. Congresswoman, I think the investment, as you asked, is necessary and urgent. We are many years behind replacing the shuttle capability. I would also add that your opening remarks were spot on. There are a number of questions that I would vouch for the fact that we in industry are poised and ready with a very capable workforce to go execute this job. Between the Congress and NASA, the Administration and industry, we are poised and capable, more than capable but a lot of strategy and acquisition and the methods to get to the goal line need to be laid out so that we can perform very well under the right conditions, so I think you have asked all the right questions.

Dr. SOWERS. Thank you, Congresswoman. I think our investment in commercial crew is justified, first of all, to protect the investment that we have made in the International Space Station. Right now the Soyuz is the only means of transportation to the ISS, and we have seen just recently that as reliable as the Soyuz has been historically, anyone can have a bad day, and if we have a bad day, then there is no access to the ISS, much less American-provided access to the ISS.

Secondly, in terms of markets we do think there is potential for additional markets for this capability. If that is true, then it will generate a tremendous number of jobs right here in the United States servicing these other markets.

Ms. JOHNSON. Thank you. My time is expired.

Chairman HALL. Thank you, Ms. Johnson. You were exactly five minutes. That is just perfection.

I ask the gentleman from California to take his five minutes. Mr. Rohrabacher.

Mr. ROHRABACHER. Thank you very much, Mr. Chairman.

Let me just note before I ask my questions that I have been surprised by a number of things in my 24 years here in Congress, but one of the things that I have been surprised the most about is the hostility that seems to be expressed towards depending on and helping promote commercial space alternatives to just government approaches to things like transportation, and this has been much to my dismay that all of the worst elements of decision making, for example, of what I call space pork and just focusing on one's own district and what government spending can be directed to one's district seems to be having a major effect on a decision that is so important to America's future as to how we will proceed into space, and I consider this to be a historic moment for our country and for this anti-commercial space alternative attitude that I see. I think it could have very grave consequences. We had, for example, the post office early on did have a fleet of airplanes, and we decided, it was decided by our country, that it would be better to contract

out airmail rather than having the government run a fleet of airplanes, and I think that decision went a long way in helping make sure that America was the number one aviation power on this planet, and I would have to say that had we had the other approach, perhaps we would have had a much more bureaucratic development of our aviation capabilities, and certainly we wouldn't have thought that having the government run airliners that only the government can run, what would that have done to America's competitive position in the world on some of the most important technological developments of the last century.

With that said, we have got some problems within the government in terms of approaching commercial, and I am not sure if it is based on hostility to commercialism or it is just a belief that we ought to have more government controls over everything, but there is a fight now between these two approaches of these contracts that the Federal Government is approaching with these private sector companies. Apparently, we have in the past—what we have and also with other types of situation, we have a Federal Acquisition Regulation which is FAR, which is a more traditional way of contracting with companies but we have instituted with the development of this commercial alternative, at least for the development stage, a system based on the Space Act agreements, and I would just ask very quickly for a comment from each one of you, and it has to be quick because I only have a couple minutes left. Is this vitally important that we move forward with an approach that was dictated by the Space Act agreement which of course I understand brings down the amount of bureaucratic costs to each one of your projects? What does that mean to your projects and your approach to space, the FAR versus Space Act agreement approach? Just a little bit from each one.

Mr. ELBON. Thank you, Congressman. Two quick comments or responses to your question. The first is, I think it is very important that we differentiate the kind of model that we are using for something like transportation to low Earth orbit that we have been doing for 50 years in capsules, it is understood, the challenges are understood, versus exploration beyond low Earth orbit that is a new thing, very much not understood, more complex, more challenging, so the level of NASA involvement in those two programs, the dependence on contractors in those two programs needs to be very different, in my view.

The second thing you asked was about a FAR versus SAA. I would say that from our perspective, this can be done with either of those instruments as long as the right environment is being put in place. Boeing will execute this with the same processes and procedures for design, for parts traceability, for configuration management, for all those kinds of things, not because the contract drives us to do that, we do these things in government programs and commercial programs like commercial airplanes because it is necessary to do those kind of things to develop a safe and reliable vehicle that can provide good transportation.

Colonel LINDSEY. Yes, Congressman. Up to this point, we have been executing under the Space Act agreements in the last couple of phases, and it has worked very well for us. We have been able to move very, very quickly, co-invest our own money, and basically

retire a lot of technology risk, and that is how it has really helped us out. Eventually as a program develops, you have to reach a point where you want to go a firm fixed price and you want to have some chance of meeting cost and schedule. That is really important to everybody. The advantage of the Space Act agreement, it gets you to the point where you can go to a FAR-based contract and succeed, and that is kind of where we are now and so the question is, when is the right time to transition, and right now, NASA is suggesting that the next phase is the right time to transition. Either way, our company will execute, but again, the Space Act agreements enabled us to move quickly and we think we can execute under FAR-based as well.

Mr. MUSK. The COTS approach has been, I think, very effective. To the degree that it can be extended, that is desirable. If it can't, then as we transition to FAR-based contracts, it is important that if the prices are fixed, that the terms are fixed and that they are based on clear hardware-based milestones. The challenge that will come with the FAR contract is if the prices are fixed but the terms are not, if the terms change over time. I think that is just common sense. But I am increasingly optimistic that it can be made to work under the right sort of FAR-based contract.

Colonel PRECOURT. Congressman, I would echo the comments from my colleagues here. I think just trying to decide based on FAR versus SAA kind of misses the point. We need to have a mechanism that enables performance and accountability, and we can perform under firm, fixed prices, John mentioned with low Earth orbit, and our understanding of it. I think it comes down to setting the organizational construct within the agreements and we can make that happen. I think NASA is stepping up in that way. They have taken the advantage of the FAR's ability to be streamlined and enable us to perform in a streamlined fashion.

Dr. SOWERS. Congressman, ULA is comfortable operating under a wide range of different contracting environments. We are comfortable with the SAA. In fact, the entire development of the EELV program was done under the OTA, the Other Transaction Authority, of the FAR which is like a Space Act. We are also very comfortable under the FAR acquisition approach but the one caution is that the requirements in the contract need to be understood very well up front, and especially in this case, the human rating requirements.

Mr. ROHRABACHER. Mr. Chairman, thank you very much, and I would like to submit for the record at this point an article in Space News by Mike Gold, who works for the Bigelow company, who is expressing his view on the regulatory requirements of the FAR approach versus the Space Act agreements approach. Thank you very much.

Chairman HALL. Without objection, it will be put in the record.

[The information appears in Appendix II:]

Chairman HALL. And I think it ought to be stated in the record too that NASA has put around $320 million in already, and most of the recipients are in this room and they are planning $4 to $6 billion that these folks will be competing for, and we are trying to make that a level competition. We just need to be sure that whoever bids can do more than sign a contract, and that the fears that

you all are here to allay, and I thank you for your comments. I don't totally agree with them but I always admire you for making them.

Next, Mr. Clarke from Michigan.

Mr. CLARKE. Thank you, Mr. Chair.

This question is for anybody who chooses to address it, but in particular for Mr. Musk. Essentially, how can the technologies developed for the Commercial Crew Program create jobs outside of the space industry, especially jobs in the automotive industry? The reason why I ask that primarily is because of the region that I represent, which is Detroit and includes metro Detroit. Now, the city that I was born and raised in, it has been affected by many tough economic forces that is creating a lot of blight in the city, so as a result, we just have acres and acres of vacant, abandoned land but it also has the infrastructure that you need—the roads, the water lines, the sewers. Also, on the positive side, we have the best manufacturing know-how around and the best trained workforce, and the best engineers in the country in metropolitan Detroit. Typically, when U.S. auto manufacturers sell more U.S.-made automobiles to folks that live in the United States, that creates jobs not only for Detroit but for our entire country, and in particular, Mr. Musk, you referenced the power of innovation resulting from the free enterprise system, you know, your career in business, you are a personal example of that success and growth. And in particular, I received information that your suppliers made around $2 almost $3 million in supplier purchases in Michigan.

So essentially it is this. This technology that you are working on, can it be leveraged to create jobs outside of the space industry to help revitalize certain areas in this country like metropolitan Detroit? I believe the answer is yes, but if you could help illustrate that for the record, any of you, that would be appreciated.

Mr. MUSK. I actually have quite a bit of knowledge of and respect for the automotive industry, and in fact, if you think about the amazing things that the automotive industry does, they create these man-rated devices called cars which are supposed to last for ten years and provide incredible safety over that period of time, and yet cost only a few tens of thousands of dollars. That is actually amazing, when you think about it. So I have really been pushing SpaceX to use more and more automotive suppliers because the quality is actually so good. And in fact, for our Merlin engine, I will give you one example, we use a company called Experimental, which does the engine jackets, outer engine jackets on our engines and does an amazing job, and we are actually hiring people from the automotive industry to bring more of that expertise and cross-pollinate into the space industry and bring the decades of expertise and trillions of dollars that have been spent on automotive and apply that effectively to that space industry. I very much agree with your point.

Dr. SOWERS. I have got one example from my company. We are currently working with a company in Michigan in the Detroit area called Rausch to take piston engine technology from the automotive industry and apply it to rocket engines. Traditionally, rocket engines have been turbo pump-based but we are doing some research right now that says that piston pumps could be superior to turbo

pumps for certain applications and the precision machining capability that we found at this company is just absolutely amazing and so we are actually looking to bring automotive technology back into the aerospace industry.

Mr. ELBON. I will just add, Congressman, that through the history of space, investments in space exploration have spun off incredible industries in the United States. As an example, the telecommunication industry, the computer industry, those all were spawned by technologies developed in space. It is often difficult to predict what the next technologies will be but there is certainly a proven track record of that investment returning a dividend.

Colonel PRECOURT. Congressman, I would add that one of the things we share in common is the manufacturing of high-tech equipment, and the automotive industry has a lot of cross-pollination. We have in our company several who have come from the automotive industry to help us with manufacturing lean processes that really increase the performance and cost value of the product, and likewise it has gone back the other way and that continues I think as we cross-pollinate and we share technologies that excite and enable improvement in both industries.

Mr. CLARKE. Thank you. Just with the brief time I have, representing metropolitan Detroit and also now newly appointed as a Member of the Science and Aeronautics Subcommittee, which I think is an extraordinary tie-in, we can show how investing in space technology can mean growth for jobs and a stronger U.S. economy over time, so I look forward to that type of partnership. Thank you very much.

Chairman HALL. I thank the gentleman.

The Chair recognizes Mr. Hultgren of Illinois.

Mr. HULTGREN. Thank you, Mr. Chairman, and thank you all for being here. I really appreciate the amazing work that you have done and continue to do. I am very excited about the future.

I have a couple of questions. Mr. Musk, I wonder if I could start and ask you a question quickly. Vertical integration is something certainly that is new to the space industry. I wonder if you could speak to how much you currently outsource to other U.S. subcontractors and how much you plan in the future to do that, and as a percentage of government program dollars, what is that percentage and how much trickles back to other smaller companies across the United States of the work that you are doing at SpaceX?

Mr. MUSK. So at SpaceX, we make all the major components of the vehicle in-house so the engine, air frame, avionics and launch operation. However, feeding into that are a vast number of smaller suppliers. Now, we have to do the major components internally in order to achieve a revolutionary improvement in the cost of space transportation because to the degree that we inherited the legacy components, we would inherit the legacy limitations and costs. But we have several hundred suppliers throughout the country and I mentioned some in the automotive industry. By value, if you look at our expenditures on a weekly basis, about half of the money is spent internally and about half is spent externally.

Mr. HULTGREN. Thank you.

I wonder for all of you, if you could address, the name of NASA's Commercial Crew Program implies a significant amount of private

investment and not simply government funding. We have talked about that a lot today and really that discussion, of how important it is. I wondered if briefly each of you could discuss just how much private investment is going into your company's commercial crew program beyond the government funding from NASA and the Department of Defense, and if you are not willing to say an amount due to proprietary concerns, I wonder if you could give a range or percentage.

Mr. ELBON. Congressman, I would characterize that our program includes the preponderance of the investment from the government. I think this is important for a couple of reasons. In order to keep the services prices low, it is important that there not be a significant investment that requires a return on that. I think it is also important that the government can be assured that a product and a service will be delivered and that the government won't make an investment that doesn't realize that because the company couldn't follow through with the investment that it was required to make.

Colonel LINDSEY. And Congressman, for us, we are a private company, so one thing that is unique about us is that because we are a private company, we invest a significant amount of money into R&D each year into various business areas. For this program, we are passionate about it, our owners are passionate about it, and our percentage right now we are running is somewhere around 40 percent is what we are investing.

Mr. MUSK. Well, if you looked at, say, our expenditures through the end of last year, our total expenditures of SpaceX time including every check we have written, we are about $800 million, and approximately 300 of that came from the government, so 500 private.

Mr. HULTGREN. Okay. Thank you.

Colonel PRECOURT. Congressman, in the case of Liberty, our concept, as I mentioned, was to leverage developed and flying elements so it has required a large amount of the startup cost and also the amount of cost you have to recoup through pricing and operations. So we have an integration cost to go to make these two elements fly together. We are leveraging huge investment from both European Space Agency and NASA on previous systems, so we have a little bit different problem in terms of business case, but we are poised to have greater than 50 percent of that remaining cost for development come from outside investment. And as I mentioned, it also does require a head nod from our customers that there is a commitment to the design and enabling the investors to climb onboard.

Dr. SOWERS. So from United Launch Alliance perspective, the rockets we are planning to use for commercial crew for Boeing, Sierra Nevada, and Blue Origin were substantially developed under commercial funds; about 80 percent of the cost of the ELB development was commercial. Going forward, the investments to human rate are quite modest and we are currently funding our participation in the Commercial Crew Program with ULA internal funds.

Mr. HULTGREN. Thank you. I just have a few seconds left, but if I can ask you each quickly just a two-sentence answer of just terminology. I wondered if you could each describe your definition of what "commercial" means.

Mr. ELBON. In the environment that we are in, I think "commercial" means that we are working towards developing markets in addition to NASA. I think that we are doing this as a company with reduced government involvement as compared to programs that we have done in the past and that we are doing this in at least a fixed-price environment where the financial risk for performance is on the companies that are participating.

Colonel LINDSEY. Sir, for us I would define "commercial" much as John did in terms of we have other markets we are looking at and we are co-investing and participating. Probably the most significant difference between what—now and what we have done in the past is when we are done with this and when we go contract for services to orbit, instead of the government actually owning the entire vehicle and operating it, they will actually pay for services where we own the vehicle and operate it jointly with them.

Mr. MUSK. Yeah, I think you are going to hear much the same answer, but essentially, "commercial" would mean that the commercial companies are deciding on the design but NASA is deciding on the objective. These are the standards and the objectives that need to be achieved, but then the solution to those standards and objectives is arrived at backed by the commercial company. And then secondly—that in terms of the funding that goes into making it happen—that there is a substantial portion of our funding that comes from entities other than the government.

Colonel PRECOURT. Congressman, I might offer a little different perspective based on a number of proposed programs that we have for different customers. We have everything from the range of a small rocket motor that serves the Pegasus launching for Orion all the way up through the space shuttle and in between. We have Minuteman missiles and the Trident missiles for the government. And in the purest sense, "commercial" means that we as the company would invest in the development completely, and then it would be based on a return on a number of sales of that product, whether it be a government or another buyer would purchase enough that we could recoup that investment. We do some of those in proposing and we do others that are purely cost-plus where the government takes on the risk.

I think in this particular environment, we are trying to get towards the place where the businesses can invest and there is enough there, but in the case of what we are doing here today, I don't know that there is enough market to draw that. So we are moving in a direction where I believe the advantage will be getting some of the benefits of outside investment while delivering on a valuable product. And I think it is laudable to try to get to a place where we are streamlined in the interface between the government and the contractors.

Dr. SOWERS. I think in the context of the Commercial Crew Program, it means that the government is purchasing a service from a private company using a commercial contract. And in that sense, all of NASA's science missions are performed that way, as well as all of our military space launches and intelligence community's space launches are done that way with the government purchasing a service from a private company.

Mr. HULTGREN. Again, thank you all.

Chairman, I have gone over. I yield back. Thank you.

Chairman HALL. Thank you for yielding back. And it might have been more in keeping with our thrust if we had the Virgin Galactic people here. Ms. Johnson and I were just talking about them. I don't know what Galactic means but I think their space port out there that they, for suborbital flights, it might be of interest to the gentleman's questions there. And it would be of interest to everybody here. We will look into that later.

Mr. Tonko of New York, you have five minutes.

Mr. TONKO. Thank you, Mr. Chair.

Good morning, gentleman, and thank you for your testimony.

Let me direct this to you—each of you. If a commercial launch vehicle experiences a serious anomaly or failure, what should NASA require of the companies before they are allowed to resume flights carrying NASA astronauts?

Mr. ELBON. I would assume as we go forward that we will follow processes and approaches like we have used for Space Shuttle, Space Station, other programs that have carried crew into orbit. If there is an incident, it is very important to stand down, understand what that incident is, resolve that incident, and fix whatever needs to be fixed before we proceed. So we will need to do things like that as we move forward.

Colonel LINDSEY. From my perspective, exactly the same thing—a full investigation needs to happen. I think the entities involved, be it the government or other folks involved, need full insight into what happened, what is going on, full investigation, study, basically nail the problem—or pound the problem down flat is a must as we have done in the past when we had anomalies. And we eventually need something called a Flight Readiness Review that everybody has to agree, including with the same opinions exposed before we are ready to go back to flight and follow a very disciplined pass—path much like NASA has done in the past.

Mr. TONKO. Mr. Musk?

Mr. MUSK. I agree with those comments. NASA is fundamentally the customer and the customer decides what they want to do next so———

Mr. TONKO. Mr. Precourt?

Colonel PRECOURT. Congressman, its root cause and then corrective action. And getting to the root cause is somewhat technically challenging at times and it requires a degree of openness and collaboration across both sides of the interface between the customer and getting to really, truly understanding what that root cause is such that the corrective action can be appropriately designed to it.

Mr. TONKO. Dr. Sowers?

Dr. SOWERS. NASA already has a working model of what you are talking about for the science missions that they purchase commercially, and they have a very rigorous certification process, that has different levels, depending on the importance of the payload. And once you are certified, if there is an anomaly, then there is a process of going back through the anomaly investigation, corrective action, and then there is a recertification that has to occur back to those same standards of rigor.

Mr. TONKO. In the case of those circumstances, who should bear the cost?

Mr. ELBON. That will be something that we will need to focus on and work as we go forward and develop the services contract. Clearly, if that risk is on the provider, the cost of service will need to be a higher amount in order to cover that risk. If the government decides to carry that risk, the price of the service could be lowered. So I think it is a cost-risk trade that will be made as we go forward and work on the services contract. Clearly, the provider community needs to step up and bear its share of that risk.

Colonel LINDSEY. Yeah, I agree. I think it will be a cost-risk trade, but ultimately, just like in design, it is our responsibility to design it adequately and test it adequately before we go flying. It is part of the root cause investigation when you have an anomaly. We will have to get at the root cause and that will be part of the determination, I think, as what caused the problem. And as a result of that, then, will probably determine who bears the most cost in this case.

Mr. MUSK. Yeah, I think it is a shared cost situation. I think there are parallels here in aviation, automotive, and—yeah, so it is going to be a shared cost so———

Colonel PRECOURT. Congressman, I think the Ranking Minority Member stated it very well with the indemnity question. I think that, as John mentioned, the services contract would be laid out such that it is clear to a certain degree. There are some very low probability events with very extremely high costs that we as companies probably would not be able to cover, and that is where the indemnification comes in is at what level does that occur and how would it be handled. When we fly off a range, there is a presumption of certification with the Air Force, and some of those costs—certainly for government missions—are borne beyond a certain liability level that protects us all.

Dr. SOWERS. I think I agree with my colleagues up here. Everyone up here has every incentive to make sure all of our missions are successful. The viability of our companies depends on being successful. The question of liability I think is one that we need to work on in the future. On commercial space missions right now, there is the Commercial Space Launch Act, which does provide some indemnification of third parties off of government ranges.

Mr. TONKO. Finally, Mr. Chair, if I might, are there any assurances—other assurances that you can offer the Members that there would be no additional hidden cost to taxpayers in the event of failure or anomaly?

Mr. ELBON. I would offer that that will be specified in the contracts that we have and it will be up to us to honor those contracts. There are lots of contracts the Boeing Company has with the government, and it is very important for us to execute on those and honor those if we are going to continue as a responsible company doing business with the government. So we will be highly motivated to do that.

Colonel LINDSEY. Part of the philosophy of this whole Commercial Crew Program is to be a firm, fixed price pay for services, no hidden costs, know exactly what we are getting into, so I think as mentioned by my colleagues, we need to nail down the indemnification and how we are going to do that before we proceed and have that as part of the contract. And then we will know so there won't

be any surprises. But I think it is really important we nail that down before we proceed forward with services contracts.

Mr. MUSK. I think it is tempting to think of space as somehow fundamentally different from other modes of transport, but I think it is not. It is a new mode of transport, or a newer mode of transport, but I think there are many parallels with other modes of transport. And NASA, for instance, purchases air tickets on airlines. And in a sense, that is extending that model to space flight. It works very well with airliners. So I don't think that this is something that should be a very fundamental concern because of parallels to other industries.

Colonel PRECOURT. I would just echo from John and Steve that setting out the right ground rules in the contract for services is really the way to address that—I completely agree with that—and being as detailed as you can up front so it is well understood and managed. We are all here to serve the customer and if we don't, then we won't be a producer for them for long———

Dr. SOWERS. Yeah, I agree. As we get further down the road with it, all those details will be worked out and at that point there will be no hidden costs.

Mr. TONKO. Thank you, Mr. Chair.

Chairman HALL. The gentleman yields back.

We all have other questions. In fact, I would like to ask about NASA oversight, what they think is necessary for the safety of passengers and the crew, but each of us will have the right to write to you and give you a reasonable amount of time to answer those questions. And we are trying to be as thorough as we can and let everybody ask all the questions they can while we have you here. That is how important you are to us.

Mo Brooks, you are recognized for five minutes.

Mr. BROOKS. Thank you, Mr. Chairman.

NASA is pursuing a commercial approach to crew transportation to the International Space Station. While the word "commercial" has been used, I am not really sure how it is used and how this approach actually exists when put against the traditional definition of commercial. And I would like to get a better understanding of the business approaches that we might be using when we use this word "commercial." And I do it in this context:

It does not seem to me that there is really a commercial market in the normal sense that you might have with airline flights or you might have with food or anything else where you have a large base of people out there that want to demand consumption of whatever good or service that might be produced. In fact, if I were to look at it in terms of private sector, non-NASA crew transportation, it would appear to me that the market is somewhere between minimal and nonexistent. You might read about the random private person who will pay money to go up in space using a Russian aircraft—excuse me—spacecraft, but that seems to be the extent of it.

And if that is the case that there is not truly a private sector commercial market that space launch companies can pursue, then I am very much concerned that we might be running into a case of inverse economies of scale. With economies of scale, generally speaking, the more you produce of something, economies of scale come into place and that product or service, whatever it is that you

are producing, the price goes down again because of economies of scale. And when I say inverse economies of scale, I am talking about where we have a limited market, if it is limited just to NASA, and we keep creating more and more companies competing for that constant slice of the pie, then in fact we are going to have increasing cost per launch rather than decreasing cost per launch.

With that concern on the record, please, if each of you would, describe for me what actions are you taking to fully explore the non-NASA crew transportation market or search for customers in the private sectors; and second, what would be the impact to your NASA pricing if you fail to capture these commercial opportunities in the private sector? And I am limiting it to human spaceflight. So with that, if all of you could respond and assist as best you can with helping us better understand the impact of this plethora of companies pursuing what appears to be a rather constant human spaceflight market.

Mr. ELBON. Thank you, Congressman. I will start by agreeing with your assessment of the market. I think that there definitely is potential for a commercial market. It is in my view, not well defined, the depth of it is difficult to estimate, and so developing a business case that depends on it is a difficult thing. So we have chosen to develop a system that will be affordable if the only transportation that we do is government transportation to ISS, that the investment, et cetera, will allow us to do that at a reasonable basis.

In parallel, though, we are also working hard to develop a commercial market independent of that. We have teamed with Space Adventures, who is the company that brokered the flights you mentioned to International Space Station on the Russian rockets, and also with Bigelow Aerospace to help provide a reliable transportation system so that Bigelow's business model serving countries who can't afford their own space program but would like to send astronauts to the space station.

So I think the fundamental thing is to develop a capability based on the transportation to space station, but at the same time, work really hard to cultivate this adjacent commercial market, and then as that matures, the cost for the NASA transportation will go down.

Mr. BROOKS. That was a part of my question. Have you or anybody else been able to ascertain any private sector market for human spaceflight, and if so, can you give us a judgment as to how many you anticipate on the private sector you could take into space on an annual basis within five or ten years?

Mr. ELBON. We traveled with Mr. Bigelow to Farnborough about a year and a half ago now and met with several of his potential clients. As I mentioned, there are sovereign entities, countries that would like to have their own space program, and we met with six of those, and I can tell you from that conversation that if there is a Bigelow Space Complex that exists and that is dependent on reliable transportation that those countries are willing to sign up now to do that. So I think the potential is there for a significant number of flights to low Earth orbit, but as I said, we aren't basing our business model on that because we don't want to not be able to execute the primary business of taking U.S. crew to space station and have that be dependent on this commercial market maturing.

Colonel LINDSEY. Yes, Congressman, we also are basing our business model on the core business, which is taking U.S. astronauts back and forth to the International Space Station, but we have been doing a lot of work looking at other markets. We think there are significant markets out there or we wouldn't be doing this investing of our own company's money in it. We think that foreign governments, other countries have already flown with the Russians and there are a lot of them out there that would like to join, I think, the international partnership that we have with the space station that is not there.

One thing I would like to point out is that the current ops concepts for how we operate the International Space Station is really based on our ability to launch and land and get resupply up to space station. And I would suggest to you that if that paradigm changes in the future, if we are successful, that ops concept will change as well just as aircraft have evolved over time and ended up doing missions you never expected them to start doing.

So I think there is a market there. I think the more we fly up in space, the cheaper the launch costs get. There is an economy of scale there. And so for all these reasons, we think there is a market—a significant market well beyond just the core of transporting astronauts to the space station.

Mr. MUSK. I think your concern about inverse economies is a good one, I think it applies only to a portion of the cost per flight. If you look at the cost per flight for transporting astronauts to the space station, at least in the case of SpaceX, about 40 percent of that is the rocket, about 40 percent of that is the non-manned elements of the spacecraft, and then maybe 20 percent incrementally is the human element. For the—for rockets, we already have two-thirds of our launches with commercial entities. So NASA has about one-third of our missions; two-thirds go to launching commercial and communications and broadcast satellites and that kind of thing.

For the spacecraft, driving the spacecraft, we already will be doing roughly four, perhaps going up to six missions per year for cargo transport to the space station. And it is the same basic spacecraft that is used for human elements. So it is really just that remaining 20 percent where there is potentially a concern of inverse economies of scale.

However, I would like to make another prediction which is that in ten years there will be more commercial flights—manned flights to space than there will be government. I am quite confident of that. But we need to have constantly improving technology. The cost needs to get lower because there are only a few people that can afford to spend $20 or $30 million just to go to space.

Colonel PRECOURT. Congressman, thanks for your question. I agree with your assessment of the market, and as a launch vehicle provider, we are looking at broader markets for other users besides crew through a common interface with multiple payloads, whether it be crew cargo, science, other satellite missions, et cetera. And so we need to be able to leverage a market that is broad like that to make this work.

I would like to add to that, though, that what I would hope would emerge from this commercial approach for NASA is a better

outcome in terms of cost affordability for a highly reliable product. And what we learned with Constellation and with Shuttle and other programs is that it comes down to how you organize with your people as to how much it is going to cost in the long term, both on the government's side and the contractor's side. And we at ATK have streamlined to the degree about 50 percent of our overheads in the last two years with essentially the same production capabilities, and that is due to the way we organize both internally and with the interface to the customer. We were able to do that because we have customer interfaces of a broad nature, all the way from pure commercial where we invested in the product and delivered it from our own internal monies and had a market that pulled on it to return that investment all the way to the full cost-plus that you are familiar with.

So in doing so, we talk a lot about, okay, so in theoretical terms, how do you get to a point which is optimum from a customer-contractor interface so that there is not too much oversight and not too little? And we began to look at it in quantifiable means and measure, and there have been a number of reports on this, but you can look a lot of my programs, and they range in two ratios that are of interest. One is what we call the contractors' workforce in support to touch labor ratio. Those ratios range in industry from anywhere from one-half of a person for every person producing a product to over three people that are doing support work for the touch labor people.

Then you look at that total labor ratio of the industry to the government, and the programs range from one industry—sorry, one government person for every four in the industry in the contract all the way to 20 industry for each government member on the contract. And so we need to use those metrics to try to drive ourselves to an optimum position, and I would hope that as we strive in this commercial crew process, we can get to those. I have seen in a lot of our commercial programs that the safety records remain very, very high even though those ratios of labor across the interfaces are much lower.

Dr. SOWERS. Congressman, United Launch Alliance is not planning to develop new rockets to support commercial crew. We are going to use the rockets that are currently flying NASA science and military payloads all built in Decatur, Alabama. From a market-sized standpoint, I agree with the rest of the panel up here that the commercial market is highly uncertain, but I think there are promising business plans like Bob Bigelow's and the traffic models I have seen from Mr. Bigelow's business plan are truly stunning. They could get the industry into a launch rate that we have never experienced before, doubling or tripling the demand that we currently see out there. So the promise is very high; the uncertainty is also very high.

Mr. BROOKS. I thank the gentlemen for your insight. And Mr. Chairman, thank you for allowing these witnesses to go way beyond my allotted time.

Chairman HALL. Your time really has expired. Thank you. But good questions and good answers. Thank you.

Now, I recognize Mrs. Lofgren, gentlelady from California.

Ms. LOFGREN. Thank you, Mr. Chairman.

This is I think a very important hearing because really I think the gentleman from Alabama's question is a good one. I have been enthusiastically supporting this effort, but the question is whether we are helping a transition or whether this is it. And there is no way to know that at this point except that the payoff is so enormous that we have to take some risks sometimes. And that is I think what we are doing at this point. I think it is a risk worth taking.

But I—one of the things I would like to know—I mean we need to have a safe product. And I am interested if you can each tell me what is the most challenging aspect of meeting NASA's safety requirements that you are facing today?

Mr. ELBON. So we are accustomed to NASA's safety requirements, having worked on Shuttle and Station most recently, but Apollo, Gemini, Mercury before that. It is kind of ingrained in what we do, so things like safety reviews, design reviews, traceability, configuration management, all of those processes are baked into our system.

And as I mentioned earlier, we have learned over the years that it is not a function of whether it is a government program or commercial program that you use those processes; we have learned that in order to have a safe, reliable transportation system, you must follow processes like that.

Ms. LOFGREN. Um-hum.

Mr. ELBON. And so the same kinds of things that we have done in the past on Shuttle, Space Station, and other programs will be implemented in our Commercial Crew Program.

Colonel LINDSEY. Yes, Congresswoman, as far as the most challenging single safety aspect, we don't really have one technical issue that is the most challenging. We also follow a process. The process is very disciplined. It is very known. Having flown on Shuttle, I really appreciate the safety process because it kept me safe, and that is exactly the same kind of process we are implementing in our design and our development in terms of safety reviews, putting the SNNA processes together, tracking all those, identifying all of our hazards, identifying our failure tolerance and establishing that.

The challenging part is doing all of it—the verification and validation of that. And our approach to those have been to team very, very closely with NASA and have them involved from the very beginning looking over from a safety standpoint, looking over our designs, identifying early those areas that we may not have enough tolerance, for example, in fixing those early. So it is process—it is a continual process. The most important thing is to stay vigilant and stay on top of that process all the way through, and that has been our approach.

Mr. MUSK. Well, the single toughest thing I think having gone through this with our Dragon spacecraft approaching the space station, where it has to be a human rate system because it is a robotic spaceship that is approaching and berthing robotically with the space station, which is $100 billion asset and it has astronauts from several countries on board. The biggest challenge is two-failure tolerance. So in other words, you have to be able to fail any two things at any time and still be okay. And when you consider

all the systems on a spacecraft, that is just very difficult to achieve. We have been able to achieve it and we are going through—this is the final verification now, but that was the single most challenging thing.

Colonel PRECOURT. Congresswoman, we also have had decades of human rating considerations driven into our processes, and our partner on Liberty, Astrium Corporation, similarly on the Ariane 5, which was designed with human rating in it for the Hermes space plane that Europe had planned brings our elements already to the table understanding and integrating human rating. The distinction that is being made at NASA right now, it is one thing to be human-rated; it is yet another to be determined that you are certified. So these new systems that we are bringing onboard have to go through a certification process even if we bring a human-rated full understanding of the requirements for human rating into the design. The question that we have is what will be the extent of the certification process that is not well known to us yet? And how many testing and verification activities and the cost of those will we have to include in our planning?

Dr. SOWERS. Congresswoman, we are also very accustomed to the rigor that is required to have repeatable success, especially given the nature of the payload to be launched for the national security community. I would say one of the interesting challenges that we are faced with is providing the abort capability, and this is one thing that all of the systems that are being talked about for Commercial Crew that Space Shuttle didn't have and that is the ability to sense an impending failure of the launch vehicle and to have the spacecraft come back safe and sound with the crew intact. And working out all those different abort scenarios is a very interesting challenge. I think it is also very worthwhile.

Ms. LOFGREN. I would just say, Mr. Chairman, looking at the timeline that NASA has provided, it is really not until 2017 that we are looking to get this mission accomplished. To me, coming from Silicon Valley, that seems like an awfully long time. Is there any possibility that we could significantly reduce that time frame in your judgment with the private sector involvement that we have?

Mr. ELBON. Congresswoman, the baseline plan that we have laid in place has us flying by late 2015. That, of course, is a function of funding. And I think it is also a function, as NASA goes forward with the program, how many providers they decide to carry and so how many providers will that funding be divided amongst. But certainly with adequate funding we can be ready to go by the end of 2015 and so start in earnest missions in 2016.

Colonel LINDSEY. Congresswoman, our internal plan also has us starting to fly by the end of 2015, so I have heard the 2017 number from NASA and I haven't talked to NASA about that number. But our internal number is 2015, and again, if we get adequate funding and—we will accelerate. If we don't get adequate funding, then the schedule is the one thing that has to give.

Mr. MUSK. Yeah, I totally agree. Six years seems like infinity. So SpaceX has only been around for nine years. During that time we developed from scratch two launch vehicles and flew them and

complex spacecraft and flew that. So I would be disappointed if this was not accomplished within 3 years.

Colonel PRECOURT. Congresswoman, acceleration is possible. It is one of the reasons we chose the Liberty concept because the elements are flying today on other vehicles and have that experience. So the long lead for us is actually the ordering of components in the supply chain and the lead time available to get those components ready to do a test flight. The other integration engineering happens in parallel, and so acceleration is feasible with the right funding profiles.

Dr. SOWERS. So given that we are using existing rockets that are flying today, we can be ready as soon as any of these other companies can provide a spacecraft to launch.

Ms. LOFGREN. Thank you, Mr. Chairman. I see my time has expired.

Chairman HALL. I thank the gentlelady.

I now recognize the gentleman from Mississippi, Mr. Palazzo.

Mr. PALAZZO. Thank you, Mr. Chairman.

Good morning, everyone. The great thing about going last I guess is I can just eliminate question after question that has already been asked and answered. But it is definitely good to see you all here today.

The Chairman mentioned something earlier about how he was excited to hear on time and within budget, and I have always liked that, too, especially within the private sector—on time, within budget, but also to the customer's satisfaction. So please don't forget that aspect of it as well.

I would like to ask each of our witnesses here today to share their perspective with this Committee on ground-based testing. What do you see the value in the ground-based testing? What have you done in regards to ground-based testing? What are you planning to do in regards to that? And also how can we also make sure that we stay focused with this critical component throughout the development and the procurement process? And we will start with Mr. Elbon.

Mr. ELBON. Ground-based testing is an important part of any development program, particularly human spaceflight development programs. You saw on the video we have test-fired a couple engines. We will be doing ascent—or an ascent-abort test that will happen without a rocket so it will go from the ground. We are integrating our avionics now in Houston. I am traveling in about a month to visit Mr. Galloway at Stennis and to look at the capabilities there and determine what kind of testing might be possible at Stennis. So we will have a comprehensive ground-based testing that is in line with what we have traditionally done on human spaceflight programs.

Colonel LINDSEY. Thank you, Congressman. That is a great question for us because actually, our philosophy on the Dream Chaser Program is test, test, test. You know, you can do thousands of wind tunnel simulations, but the best wind tunnel in the world is to actually go drop test and see if your vehicle really flies. You take more programmatic risk, but we think you can accelerate and go faster doing that. So we are all about test. And the first phase of the program, instead of just coming up with a Power Point vehicle,

we actually built a real vehicle, put it in University of Colorado's earthquake lab and tested it structurally. We did drop-model tests; we have done all kinds of testing. Our rocket motors, which are actually the same rocket motors that are used by Virgin Galactic for SpaceShipOne and SpaceShipTwo are extensively tested on the ground, and we continue to test those.

Every component, every aspect of what we do will be ground-tested, so we think it is invaluable to do all of that before we go into flight test and we think it enables us to move faster and accelerate our program by doing an extensive amount of testing.

Mr. MUSK. At SpaceX we do a great deal of ground-testing, but I should point out that we also flight-tested our launch vehicle and our Dragon spacecraft. So it is not just the ground-testing. We do—actually flight-test the vehicles and there is going to be a great deal of flight-testing to come. One of the big milestones is coming in about 3 months or so where we will dock with the space station or berth with the space station. And so that should be pretty exciting.

Colonel PRECOURT. Congressman, flight-testing is critical, and many of the people in your State know that very, very well and we have worked for decades in many NASA programs exploiting the test capabilities in Mississippi. We actually have a plan with Liberty at leveraging a lot of testing that has already gone on behind us and then to leverage existing facilities like at Stennis and other places in the country that would further mitigate the risks of the systems as we take them into flight.

Testing is all about a build-up approach. An example I can give you is we removed 1,500 pounds from the weight of our booster. We didn't do that on one fell swoop; we did it incrementally over several ground tests. And when you are handling 3.5 million pounds of thrust, you have to do that with a build-up approach, not jumping to the end state immediately. So that testing is ultimately critical to the reliability that we get out of the product.

Dr. SOWERS. Congressman, ground-based testing is fundamental to our philosophy of mission assurance. For every rocket that we fly, every part is tested as a part. They are built into subsystems and tested at the subsystem level. They are built further up into systems and tested at the system level. And then finally, the whole rocket is integrated on the launch pad and tested as an entire rocket, and that is before every single flight, and that is key to establishing repeatable mission success.

Mr. PALAZZO. I appreciate that. When we had an opportunity to talk to Commander Cernan I asked him the importance of ground-based testing, and he pretty much said everybody that we sent up to the moon came home from the moon safely. So it is extremely important to our space program that we stayed committed to testing and we don't try to take shortcuts, fly before we test, save costs, I don't think that is in the best interest of the program at all.

Chairman HALL. Judge Miller has kindly said that he will not ask any more questions, but he like others that were here have been on other committees during this time and knows that we have the full report to read. And Judge, thank you for yielding your time.

Mrs. Adams is here. She has five minutes if she would like.

Mrs. ADAMS. Thank you, Mr. Chair.

Chairman HALL. Thank you for being here with us.

Mrs. ADAMS. Thank you. I am sorry I am late. I was in another committee.

I understand that with the recent failure of the Russian cargo mission, it highlighted some problems with depending on foreign countries to access ISS, so we need to build capacity for American astronauts to reach space on U.S. spacecraft and U.S.-built spacecraft built quickly but safely and with, I would believe, aggressive oversight by Congress based on what has happened in the past.

Mr. Musk, can you talk about the importance of your rocket being 100 percent made and what business advantage you gain from that?

Mr. MUSK. One hundred percent even American-made? I believe it is important to avoid a foreign dependency on American launch vehicles. You never know what the future security situation of the world will look like. And so in order to have good control over our costs and not face potential future foreign dependency, we sourced the vehicle 100 percent in the United States.

Mrs. ADAMS. And what is your biggest concern with the management of the Commercial Crew Program?

Mr. MUSK. Well, I should say right now I think NASA is doing a pretty good job. Going forward, the most important thing is that the terms and the costs be well defined. Where things can go wrong is if the price is fixed but then the terms change over time and that is obviously not a workable situation for any contract.

Mrs. ADAMS. In the document given to the Committee dated February 19, 2008, SpaceX laid out an ambitious schedule which has all demonstration flights for commercial crew ending in April of next year. Can you tell the Committee what NASA can do to help you meet any schedule you lay out in the future and why the demonstrations have been so delayed?

Mr. MUSK. Okay, but that could be a bit of a longer answer.

So we are getting ready to do our first flight to the space station, which I think could occur in the January time frame. So I think that is doing pretty well. I think by the standards of the space industry, I think we are doing very well on schedule. The space industry is not known for being on time, so I guess if you are running a little bit late, that is maybe by most other standards being on time. I hate to say that but it is unfortunately true. And you know, I think I feel highly confident that if the funding is there for commercial crew that we can get crew safely to the station and back within three years.

Mrs. ADAMS. Mr. Precourt, could you tell the Committee how much money that ATK spent on this application and CCDev–2?

Colonel PRECOURT. How much we invested in going through the CCDev–2? We have a partner in Astrium from Europe, and together in putting together our program, we took the concept to a systems requirements review on our own funding, and it is north of $10 million.

Mrs. ADAMS. And were you told that both launch vehicles and spacecraft were eligible for awards under CCDev–2?

Colonel PRECOURT. That was NASA solicitation. They specifically requested elements of vehicle, of spacecraft services such as launch vehicles and spacecraft.

Mrs. ADAMS. Thank you. I yield back.

Chairman HALL. Ms. Adams yields back.

I think we really want to thank you for your good time. And I just want to comment on Ms. Lofgren's question because she asked a good one about acceleration of those dates, 2017 and 2020. They seem a little far off to me but I can remember we are in an emergency, and this country is in an emergency right now. NASA is in an emergency. Our space program is in an emergency. We can do better than those dates I think, and I refer to a time back toward the end of World War II when the Japanese were headed for Midway and we had broken their code; we knew they were coming. We had two aircraft carriers, one of them ready for battle, the other being worked on in Pearl Harbor to be worked on for eight months Admiral Nimitz went aboard it on Monday and said by Thursday we are going to go out of here and meet the other. We only had two aircraft carriers to fight to five aircraft carriers that were attacking us. They did it in those five days. And somebody just needs to say damn it, let us go. And I think you all are the ones to do it and hope you will.

And I thank the two astronauts who are there and all five of you. I am very grateful to you. We do have Garrett Reisman who has—flown three shuttle missions. I recognize him. And Bob Walker who chaired this Committee is here. We welcome you, Bob. And we are going to close this hearing in just a few minutes with thanks to Bart Gordon for the four years he served here.

The round of questions are completed, and I thank you for your testimony. If Members of the Committee have additional questions for anyone, we will write to you and ask you to respond to those in writing if you will.

You are excused. You can stay if you like. You are welcome to stay; you are wanted to stay. I know how busy you are. You are not going to stay, but we once again on behalf of all—everybody here, we really do appreciate you and the time you have given us, each one of you.

Okay. At this time we will get our very patient second panel seated, I want to welcome you, too. Our first witness on the panel is the Honorable Paul Martin, the Inspector General of NASA, who was confirmed in November 2009. Prior to NASA, Mr. Martin served as Deputy Inspector General at the U.S. Department of Justice, a great background and good for service now. Mr. Martin, we are really delighted to have you here.

Our second witness on the panel is Bill Gerstenmaier, a very knowledgeable Associate Administrator of the Human Exploration and Operations Mission Directorate. We don't need any of that at NASA. He has been at NASA since 1977, led a number of activities with the Space Shuttle and the Shuttle Mir and International Space Station before becoming Associate Administrator for Space Operations prior to this summer. Mr. Gerstenmaier, thank you for your leadership in ensuring safe and successful human spaceflight program and for coming before us today.

As our witnesses should know, spoken testimony is limited to five minutes after which Members will have five minutes each to ask questions. We won't hold you to the five minutes. Stay as close as you can but we are honored to have you and we will be very lenient. We don't have a hook or anything. If they go a little over when they are as important as you two are.

So at this time, I will recognize Mr. Martin to present his testimony.

STATEMENT OF THE HON. PAUL MARTIN, INSPECTOR GENERAL, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. MARTIN. Thank you, Mr. Chairman, Members of the Committee. Thank you for inviting me here today to discuss the progress made and the challenges remaining with NASA's efforts to encourage a market for privately owned commercially operated space transportation.

To date, NASA has spent $320 million in its commercial crew development effort, most recently making awards to four companies to help foster a commercial space industry that can meet NASA's need to transport its crews to the International Space Station. Although NASA has over 50 years of experience with contractor-built government-owned space vehicles, it has never purchased transportation for its astronauts aboard a commercially developed system. Of primary concern in this new paradigm is how NASA will work with its commercial partners to ensure that their vehicles meet NASA's safety and human rating requirements. How NASA addresses this challenge will to a large degree determine whether the nascent commercial space transportation industry can evolve into a viable commercial enterprise.

To examine NASA's progress as it transitions from its traditional role of owning human spaceflight vehicles to purchasing these services, the Office of Inspector General reported this summer on the Agency's efforts to modify its safety and human rating requirements and acquire and certify commercial crew transportation services. Our June 30 report concluded that NASA has made sustained progress toward its goal of obtaining commercial transportation services to low Earth orbit. At the same time, we identified a series of significant challenges. My written statement summarizes each of these challenges, and I will not attempt a summary of that summary here. But let me highlight three important issues.

First, NASA has not finalized the process it will use to certify that a commercial partner's vehicle can safely transport NASA personnel. Every requirement NASA imposes has a cost associated with it in time, money, or potentially decreased innovation. Conversely, incurring these costs is often necessary to appropriately manage risk, particularly when the issue is human crew as opposed to cargo. In the coming months, NASA must finalize a set of crew safety requirements that help reduce development and operation costs for its commercial partners.

Second, NASA has recently announced acquisition strategy that calls for a firm fixed-price contract in its first phase. NASA's decision to move away from funded space act agreements toward far-based contracts has drawn criticism from some quarters over fears

that it may create administrative burdens and reduce the control companies have over their own system designs. NASA counters that its contract eliminates much of the time-consuming paperwork of a more traditional far-based contract. Going forward, one of the key challenges for NASA is to strike a balance that will enable innovation and flexibility, yet provide the appropriate amount of direct government involvement to ensure the safety of NASA astronauts, which leads to my third and final point.

NASA initially plans to operate in an insight role while companies are beginning development of their launch systems. In later stages, NASA may assume more oversight role in directing or granting approval to partners on the path to certification. Selecting the appropriate level and mechanisms of insight and oversight will be critical to provide NASA with sufficient information to assess partners' technical, schedule, and cost risks with the goal of certifying that commercially developed vehicles are safe for NASA astronauts, all without unduly affecting the commercial partner's ability to operate in a cost-effective manner.

Mr. Chairman, this concludes my prepared statement. I would be pleased to answer any questions, preferably easy questions. I would leave the hard ones to my colleague. Thank you.

[The prepared statement of Mr. Martin follows:]

PREPARED STATEMENT OF THE HON. PAUL MARTIN, INSPECTOR GENERAL, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. Chairman and Members of the Committee:

Thank you for inviting me to discuss the progress made—and challenges remaining—with NASA's efforts to develop privately owned, commercially operated crew launch capabilities.

With the final Space Shuttle flight in July 2011, the Agency turned its attention to the manned space program called for in the NASA Authorization Act of 2010 while continuing to encourage development of commercially operated U.S. space transportation systems. When these commercial capabilities are matured and available to the Government and other customers, NASA intends to use them to replace its reliance on the Russian Soyuz for transporting astronauts to the International Space Station (ISS).

The emergence of commercial companies seeking to provide access to the ISS and low Earth orbit presents NASA with both opportunities and challenges. In April 2011, NASA announced a second round of funded Space Act Agreements with four companies totaling $269.3 million as part of the Agency's Commercial Crew Development (CCDev) effort. NASA has since reported that these four companies—Blue Origin, Boeing, Sierra Nevada Corporation (Sierra Nevada), and Space Exploration Technologies Corporation (SpaceX)—have successfully met all initial milestones set for them. Furthermore, NASA has amended its agreements with Boeing and Sierra Nevada to include optional milestones for specific tests intended to accelerate development efforts. If met, these new milestones bring the potential value of the companies' agreements to $112.9 million and $105.6 million, respectively.

Additionally, in July 2011 NASA and United Launch Alliance (ULA) entered into an unfunded Space Act Agreement to share personnel, infrastructure, and information to accelerate the potential use of ULA's Atlas V launch vehicle as part of a commercial crew transportation system. Similarly, last month NASA and Alliant Techsystems (ATK) entered into an unfunded Space Act Agreement to collaborate on the development of ATK's commercial launch system known as Liberty. Under the agreement, ATK and NASA will review and discuss Liberty system requirements, safety and certification plans, computational models of rocket stage performance, and avionics architecture designs.

These Space Act Agreements illustrate the progress NASA has made to date with its CCDev initiative. However, significant challenges remain as NASA attempts to cultivate privately owned, commercially operated crew launch capabilities and foster a commercial space industry that could meet the Agency's low Earth orbit crew transportation needs. Although the Agency has over 50 years of experience with con-

tractor-built, Government-owned space vehicles, NASA has never procured transportation for its astronauts aboard a commercially developed vehicle. Of primary concern in this new paradigm is how NASA will work with its commercial partners to ensure that commercially developed vehicles meet NASA's safety and human-rating requirements, which seek to ensure that spaceflight systems accommodate human needs, control hazards, manage safety risks and, to the maximum extent possible, provide the capability to recover the crew safely from hazardous situations. How NASA responds to this challenge will to a large degree determine whether the nascent commercial space transportation industry evolves into a viable commercial enterprise that meets NASA's crew transportation needs. To examine NASA's progress as it transitions from its traditional role of contracting for and owning human spaceflight vehicles into the role of purchasing crew transportation services from industry, the Office of Inspector General (OIG) earlier this summer reported on the Agency's efforts to modify its existing safety and human-rating requirements to make them applicable to commercially developed vehicles. We also evaluated the overarching challenges associated with possible approaches NASA may use to certify and acquire commercial crew transportation services.

Our report, issued on June 30, 2011, concluded that NASA has made sustained progress toward its goal of obtaining commercial transportation services to low Earth orbit.[1] At the same time, we identified a series of challenges NASA faces as it expands its Commercial Crew Transportation program:

- modifying NASA's existing safety and human-rating requirements for commercially developed systems;
- managing its acquisition strategy for commercial crew transportation services;
- implementing the appropriate insight/oversight model for commercial partner vehicle development;
- relying on an emerging industry and uncertain market conditions to achieve cost savings; and
- managing the relationship between commercial partners, the Federal Aviation Administration (FAA), and NASA.

I summarize each of these challenges in turn.

Modifying NASA's Existing Safety and Human-Rating Requirements for Commercially Developed Systems. In December 2010 NASA issued a consolidated set of health and medical, engineering, and safety and mission assurance requirements that commercial partners will have to meet to obtain certification to transport astronauts ("Commercial Crew Transportation System Certification Requirements for NASA Low Earth Orbit Missions "). These Requirements describe NASA's certification philosophy; the content and timing of the certification packages commercial companies will be required to deliver to NASA; and NASA's expectations for system safety, human control of the vehicle, and crew survival. In addition, the Requirements reference a set of 93 other documents, each containing additional requirements the companies must consider in order to obtain certification. NASA has categorized the underlying 93 documents into three types: Type 1–mandatory, must be implemented as written; Type 2–alternatives allowed with NASA approval; and Type 3–suggested best practices. Each of the 93 documents reference other documents that set forth additional requirements. According to one estimate, NASA's Certification documents contain more than 4,000 requirements. However, NASA has not finalized the processes Agency officials will use to verify that commercial partners have met these requirements and certify that a commercial partner's vehicle can safely transport NASA personnel. In May 2011 the Agency released for industry comment six draft documents (the 1100–series) that supplement the Certification Requirements relating to missions to the ISS. These documents provide additional information to commercial partners regarding roles and responsibilities, technical management processes supporting certification, crew transportation system and ISS services requirements, and the application of technical and operations standards.

Since issuance of our report, NASA has received industry's feedback, reviewed and updated the 1100–series documents, and is working to validate the requirements for development of commercial services to deliver crew to the Space Station. Updates to these requirements will continue through the formal NASA document change process with final approval and release planned for early November 2011.

Despite the absence of finalized requirements from NASA, the private sector is already developing systems and vehicles to meet NASA's crew transportation needs.

[1] "NASA's Challenges Certifying and Acquiring Commercial Crew Transportation Services," NASA Office of Inspector General (June 20, 2011) accessible at http://oignasa.gov/audits/reports/FY11/IG–11–022.pdf.

During the comment phase, companies have suggested that NASA (1) modify existing requirements to the greatest extent possible and ensure they are achievable so that industry fully understands what is expected; (2) coordinate with the FAA —which has regulatory oversight of U.S. companies providing commercial space transportation services —to ensure NASA requirements and FAA regulations are compatible; and (3) allow for flexibility so that changes in vehicle or system design are attainable within reasonable costs. For its part, NASA said that it has reduced its compliance documents to those truly necessary to meet Government requirements. Additionally, the Agency has stated that it will allow commercial partners to propose alternative standards, where applicable.

Every requirement NASA imposes on commercial vehicles has a cost associated with it in time, money, or decreased innovation. Conversely, incurring these costs is often necessary to appropriately manage risk, particularly when the issue is human crew as opposed to cargo. Consequently, many of the requirements NASA will impose on its commercial partners are the same as those the Agency applies to its own spaceflight programs. NASA must determine if, when, and how it will oversee commercial partners' development efforts in order to ensure they meet Agency requirements and maximize safety and reliability without burdening commercial partners with unnecessary demands that lead to higher development and operations costs.

Managing the Acquisition Strategy for Commercial Crew Transportation Services. When we issued our report in late June, NASA was still developing its acquisition strategy and had not settled on the specific mechanisms it planned to use for procuring commercial crew transportation services. Therefore, our report discussed the financial and programmatic challenges of several possible strategies, including those that rely on funded Space Act Agreements; competitive procurements, in particular fixed-price contracts; or a combination of both.

With respect to funded Space Act Agreements, we reported that their use limits Government control compared to traditional procurement contracts based on the Federal Acquisition Regulations (FAR). As one potential customer of the private sector market, NASA expects CCDev Space Act Agreements to result in commercial capabilities that consider the Agency's Certification Requirements. However, under such agreements the Agency cannot dictate specific system concepts or elements or mandate compliance with its requirements. Rather, commercial partners are free to determine the system requirements and concepts they believe will best serve their target markets. Because crew transportation for NASA is the most viable segment of the human spaceflight market in the short term, it is in the companies' best interests to ensure compliance with NASA requirements if they hope to obtain NASA's business. Nevertheless, the lack of mandatory compliance with NASA's requirements would have presented some risk that differences between partner designs and Agency requirements could occur. In addition, according to Agency policy, NASA may only enter into funded Space Act Agreements when its objective cannot be accomplished through a contract, grant, or cooperative agreement. Moreover, under the law a procurement contract is required if NASA is the sole beneficiary of the expected deliverables.

Similarly, we reported that the use of fixed-price contracts for crew transportation services also presented challenges. Traditionally, cost-reimbursement rather than fixed-price contracts have been used on projects in which costs and risks are not clearly defined. While fixed-price contracts lock in the Government's initial investment, proceeding in this manner may not eliminate cost risks. Some of NASA's potential commercial crew partners are building spacecraft for the first time and design and development are under way without fully defined and finalized requirements. In this type of environment, there is a risk that during the period of contract performance NASA's requirements may change so significantly that contractors could successfully argue that the Agency is changing the contract's scope, in which case NASA could be required to pay the contractor to make necessary modifications.

In September 2011, NASA released an outline of its acquisition strategy to achieve a certified crew transportation capability from private industry no later than the end of fiscal year 2016. The draft request for proposal calls for a firm fixed-price Commercial Crew Integrated Design Contract in the first phase to be awarded to one or more companies that will result in a complete end-to-end design compliant with NASA Crew Transportation System requirements, including spacecraft, launch vehicle, launch services, ground and mission operations, and recovery. The contract value could be up to $1.61 billion from July 2012 through April 2014. In the second phase, NASA will issue a separate, formal solicitation for follow-on contracts for development, test, evaluation, and certification activities with optional ISS service flights.

NASA's decision to move away from funded Space Act Agreements and toward FAR-based contracts has drawn criticism from some quarters over fears that this approach may cause significant delays and limit the flexibility of participating companies. In rolling out its new strategy, NASA has described it as a non-traditional contract approach that eliminates certified cost and pricing and Cost Accounting Standards requirements and incorporates tailored requirements, limited deliverables, and focused insight and oversight. Nevertheless, industry representatives have expressed concerns that NASA's plans for a more hands-on FAR-based approach may be prohibitively expensive, create undue administrative burdens, and curtail the innovation and control they have over their system designs. Conversely, NASA believes the risk of commercial partners' inability to meet its human-rating requirements could cause costly and time-consuming redesigns, pose safety concerns, and require NASA to be more involved in the development of any commercial transportation system. Going forward, one of the key challenges for NASA will be to strike a balance that will enable innovation and flexibility yet provide the appropriate amount of direct Government involvement to ensure the safety of NASA's astronauts.

Establishing the Appropriate Insight/Oversight Model for Commercial Partner Vehicle Development. In selecting the timing and appropriateness of its procurement mechanisms, NASA must balance its role as a supporter of commercial partners with its responsibility to ensure that commercially developed vehicles are safe for NASA astronauts, meet the Agency's needs, and provide for a viable domestic alternative to the Soyuz vehicle. As we reported in June 2011, the Commercial Crew Office is in the process of developing the model for NASA's insight and oversight of commercial companies. According to NASA policy, "insight" means acquiring knowledge and an understanding of contractors' actions by monitoring selected metrics and milestones. Methods of achieving insight include reviewing documents, attending meetings and tests, and conducting compliance evaluations. "Oversight" combines technical insight of contractor activities with approvals that provide the contractor with formally documented authority to proceed or formal acceptance of plans, tests, or other criteria.

With the issuance of the draft request for proposal for the Commercial Crew Integrated Design Contract, NASA has confirmed that it plans to function in an insight role while commercial partners are designing and beginning development of their launch systems. For example, the Agency intends to assign a core Partner Integration Team comprised of NASA employees to follow each contractor as they design and begin to develop their systems, performing insight activities at commercial facilities as needed. Additionally, a board headed by a NASA Commercial Crew Program Manager and co-chaired by an industry representative will approve commercial systems and determine whether they meet NASA requirements.

As each contractor moves forward with development, demonstration, and flight test activities, NASA will still need to maintain insight into the development of each vehicle but may assume more of an oversight role in granting approval or direction to each partner on the path to certification. To our knowledge, NASA has not finalized the oversight model for this phase that will include defining the key milestones commercial partners must successfully meet. Selecting the appropriate level and mechanisms of insight and oversight is critical to provide NASA with sufficient information to assess partners' technical, schedule, and cost risks and certify that commercially developed vehicles are safe for NASA astronauts without unduly affecting the commercial partners' ability to operate in a cost-effective manner.

Relying on an Emerging Industry and Uncertain Market Conditions to Achieve Cost Savings. In the NASA Authorization Act of 2010, Congress stated that commercial companies offer the potential of providing lower cost crew transportation services to support the Space Station. In fact, NASA's acquisition strategy for procuring crew transportation services is premised on competition and a healthy commercial human spaceflight industry that would allow NASA to solicit bids from a number of partners and make informed, competitive procurement decisions that meet individual mission requirements and provide the best value for the taxpayer. However, the commercial human spaceflight industry is in its infancy and the market beyond NASA's own crew transportation needs is uncertain. Many of the risks associated with achieving anticipated cost savings are largely out of NASA's control, particularly in the area of creating non-Government demand for commercial human spaceflight services. The 2010 Authorization Act directs NASA to work with the Federal Aviation Administration's (FAA) Office of Commercial Space Transportation and assess the potential non-Government market for commercially developed crew and cargo transportation systems and capabilities. In April 2011, NASA and the FAA reported that over time the market for commercial crew and cargo services may emerge and provide significantly more customers, more flights, and potentially

lower prices to the U.S. Government. The continuing challenge will be to determine at what point the market can sustain a number of commercial partners, allowing NASA to transition to the role of consumer and ultimately realize cost-effective commercial crew transportation.

Managing the Relationship Among Commercial Partners, the FAA, and NASA. The FAA is responsible for regulatory oversight of companies seeking to provide commercial human space transportation. To date, the FAA has issued regulations pertaining to launch and reentry activities that could affect the public safety. However, in December 2012 the FAA is authorized to begin proposing regulations concerning the safety of passengers and crew involved in commercial spaceflight. As previously discussed, NASA plans to impose its own set of requirements, standards, and processes that commercial partners must meet to obtain a certification before transporting Agency personnel. Accordingly, NASA must coordinate with the FAA to avoid an environment of conflicting requirements and multiple sets of standards for commercial companies seeking to transport Government and non-Government passengers to low Earth orbit. Toward that end, the FAA and NASA have expressed a spirit of cooperation, and both groups have agreed that the ultimate goal is FAA licensing of commercially developed vehicles used to transport NASA personnel. Additionally, the agencies are co-locating personnel at NASA Headquarters, FAA field offices, and Johnson and Kennedy Space Centers to optimize Government oversight of commercial partners through compatible requirements, standards, and processes.

While we did not make specific recommendations for corrective action in our June report, we continue to believe NASA must pay particular attention to these challenges as it continues to partner with commercial companies seeking to provide safe, reliable, and cost-effective access to the ISS.

This concludes my prepared statement. I would be pleased to answer any questions.

Chairman HALL. That makes sense to me.

I now recognize Mr. Gerstenmaier to present his testimony. And he will accord you the same opportunity I am sure.

STATEMENT OF MR. WILLIAM H. GERSTENMAIER, ASSOCIATE ADMINISTRATOR, HUMAN EXPLORATION AND OPERATIONS MISSION DIRECTORATE, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. GERSTENMAIER. Thank you, Mr. Chairman.

The Commercial Crew Program represents a shift in near Earth operations to the private sector, freeing NASA and NASA's limited resources to pursue other human spaceflight goals including the utilization of the International Space Station and setting out on missions of exploration.

Commercial Transportation Systems, together with the capabilities to explore deep space provided by the Space Launch System and by the Orion Multipurpose Crew Vehicle will enable NASA to move forward on a robust, comprehensive U.S. human spaceflight program. We had the right mix of government-managed programs and new commercial acquisitions. Technical considerations drove these acquisition approaches.

NASA is committed to managing the requirements, standards, and processes for Commercial Transportation Systems certification to ensure that the commercial missions are held to the same safety standards as government missions. NASA will be responsible for defining, managing, reviewing, and approving certification plans and verifying requirements related to commercial crew program missions. However, more direct accountability will be shifting to the commercial companies providing these services to NASA.

We have listened to the comments from the IG, the Aerospace Safety Advisory Board, and the GAO. We have amended our acquisition approach based on their input. We have listened to industry's

comments from the draft RFP and learned from cargo transportation experiences. We have worked corporately with the IFA and worked cooperatively with the FAA. We have attempted to strike a balance among the many competing objectives. The plan that we have will have many challenges and will not be easy to execute. We will continue to listen and adapt as we move forward. We have put together a solid plan to deliver safe and reliable crew transportation for the Nation at low cost.

NASA's 2012 budget request of $850 million in fiscal year 2012 for the Commercial Crew Program would provide for the development of commercial crew transportation system designs with crew transportation services available to the ISS in 2016. Reduction in funding from the President's request could significantly impact the program's schedule, risk posture, and acquisitions strategy. NASA's initial analysis shows that a 2012 funding level of $500 million consistent with the 2010 NASA Authorization Act would delay initial capability to the ISS to 2017 assuming additional funding is available in the out years. During that roughly one-year period of delay, NASA would be paying approximately $480 million to Russia for crew transportation services. Therefore, NASA seeks funding for the Commercial Crew Program and the final conference action on the fiscal year 2012 appropriation as close to the NASA fiscal year 2012 request as possible.

Providing inadequate funding to this delicately balanced acquisition approach represents an unacceptable risk to program execution and would force us to relook at our overall approach. We need the appropriate funding for this challenging program. The commercial program is the Nation's strategy for ending sole reliance on the Russians for crew transportation capability to the space station. Private enterprise and affordable commercial operations in low Earth orbit will enable a truly sustainable step in our expansion into space.

NASA plans to acquire these services in a unique, cost-effective, and timely manner that will maintain safety for the crew. This acquisition will have many challenges. NASA is addressing these challenges in a systematic way. We will need your continued support and help in supporting this program.

This program is part of a larger plan for the exploration of space that will keep the United States a leader in space exploration. I look forward to your questions and thank you.

[The prepared statement of Mr. Gerstenmaier follows:]

PREPARED STATEMENT OF MR. WILLIAM H. GERSTENMAIER,
ASSOCIATE ADMINISTRATOR, HUMAN EXPLORATION AND OPERATIONS
MISSION DIRECTORATE, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. Chairman and Members of the Committee, thank you for the opportunity to appear before you today to discuss NASA's efforts to support the development of commercial crew transportation systems. We are pleased with the progress our industry partners have made in this new and innovative approach to human spaceflight development. Their success is critical to ensuring that we re-establish an American capability to transport U.S. astronauts—and their cargo—to the International Space Station (ISS), and quickly end the outsourcing of this work to foreign governments. And they need robust funding from NASA, to achieve timely success in this critical endeavor. Not only will the availability of one or more commercial crew transportation systems represent the emergence of a brand new domestic capability for carrying our astronauts to Low Earth Orbit (LEO) and the ISS, it will also

enable the Agency to focus on developing its own systems for sending astronauts on missions of exploration beyond LEO.

Commercial Crew Development (CCDev)

NASA's investments have been aimed at stimulating efforts within the private sector to develop and demonstrate human spaceflight capabilities through the CCDev initiative. Since 2009, NASA has conducted two CCDev rounds, soliciting proposals from U.S. industry participants to further advance commercial crew space transportation system concepts and mature the design and development of elements of the system, such as launch vehicles and spacecraft. In the first round of CCDev, NASA awarded five funded Space Act Agreements (SAAs) in February 2010, which concluded in the first quarter of 2011. Awardees and the amounts of the awards were: Blue Origin, $3.7 million; the Boeing Company, $18 million; Paragon Space Development Corporation, $1.44 million; Sierra Nevada Corporation, $20 million; and United Launch Alliance, $6.7 million. Under these SAAs, companies received funding contingent upon completion of specified development milestones. All milestones were successfully accomplished by the CCDev industry partners.

During the second CCDev competition, known as CCDev2, NASA awarded four funded SAAs that are currently being executed with the following industry partners:

- Blue Origin's work involves risk-reduction activities related to development of a crew transportation system comprised of a reusable biconic shaped Space Vehicle launched first on an Atlas V launch vehicle and then on Blue Origin's own Reusable Booster System. The company is working to mature its Space Vehicle design through Systems Requirements Review (SRR), maturing the pusher escape system, and accelerating engine development for the Reusable Booster System. As of September 30, 2011, Blue Origin had successfully completed five of ten milestones and NASA had provided $11.2 million of the $22 million planned for this effort.
- The Boeing Company is maturing its commercial crew transportation system through Preliminary Design Review (PDR) and performing development tests. Boeing's system concept is a capsule-based spacecraft reusable for up to ten missions that is compatible with multiple launch vehicles. Boeing's effort will include launch abort engine fabrication and static test fire, landing air bag drop demonstration, wind tunnel testing, parachute drop tests, Service Module Propellant Tank Development Test, and Launch Vehicle Emergency Detection System/Avionics System Integration Facility Interface Simulation Test. As of September 30, 2011, Boeing had successfully completed five of fifteen milestones and NASA had provided $52.5 million of the $112.9 million planned for this effort milestones.
- Sierra Nevada Corporation (SNC) is maturing its commercial crew transportation system, the Dream Chaser, through PDR with some subsystems to Critical Design Review (CDR). The Dream Chaser is a reusable, piloted lifting body, derived from NASA's HL–20 concept that will be launched on an Atlas V launch vehicle. SNC's effort also includes fabrication of an atmospheric flight test vehicle, conducting analysis and risk mitigation, and conducting hardware testing. As of September 30, 2011, SNC had successfully completed four of thirteen milestones and NASA had provided $30 million of the $105.6 million planned for this effort.
- SpaceX is maturing its flight-proven Falcon 9/Dragon transportation system focusing on developing an integrated, side-mounted Launch Abort System. The uncrewed version of Dragon is already being demonstrated as part of the Commercial Cargo project, and will be used operationally as part of the ISS cargo resupply services effort. Their crew transportation system is based on the existing Falcon 9 launch vehicle and Dragon spacecraft. The Launch Abort System, an essential safety-critical system, represents the longest-lead portion of the Falcon 9/Dragon crew transportation system. As of September 30, 2011, SpaceX had successfully completed four of ten milestones and NASA had provided $40 million of the $75 million planned for this effort.

In addition to the four funded agreements mentioned above, NASA has also signed SAAs without funding with three companies: Alliant Techsystems, Inc. (ATK); United Launch Alliance (ULA); and Excalibur Almaz, Incorporated (EAI). The ATK agreement is to advance the company's Liberty launch vehicle concept. The ULA agreement is to accelerate the potential use of the Atlas V as part of a commercial crew transportation system. The EAI agreement is to further develop the company's concept for LEO crew transportation. As of September 30, 2011, ATK

had successfully completed one of five milestones; ULA successfully completed two of five milestones. NASA and EAI are initiating activities under the SAA now, and milestones are planned to continue through May 2012.

Commercial Crew Program (CCP)

The CCP is a partnership between NASA and the private sector to incentivize companies to build and operate safe, reliable, and cost effective commercial human space transportation systems. In the near term, NASA plans to be a reliable partner with U.S. industry, providing technical and financial assistance during the development phase. In the longer term, NASA plans to be a customer for these services, buying transportation services for U.S. and U.S.-designated astronauts to the ISS. We hope that these activities will stimulate the development of a new industry that will be available to all potential customers, including the U.S. Government.

Success of the CCP would also end the outsourcing of space transportation to foreign providers. Together with the capabilities to explore deep p space provided by the Space Launch System and the Orion Multi-Purpose Crew Vehicle, NASA is moving forward on a robust, comprehensive U.S. hum man spaceflight program. Reductions from the President's FY 2012 requested funding level would affect our ability to successfully implement this program's procurement strategy, and could leave us depend dent on foreign transportation services for a longer period of time at a cost of approximately $480 million per year. The success of this program will ensure that U.S. companies will provide these services.

Commercial Crew Program Acquisition Roadmap

The CCP acquisition lifecycle is comprised of an overall hybrid structure that originated d with the funded SAAs for subsystem, system and element design during the separate CCDev efforts, to be followed by a series of competitively awarded contracts for an integrated Crew Transportation System (CTS). NASA's review and analysis led to the development of a phased acquisition strategy incorporating separate, sequential, full and open competitions, tailored to meet the Program objectives throughout each phase of design, development, test, evaluation, certification, and ISS transportation services. A combination of funded agreements and contracts for separate phases was determined to be the ideal strategy to capitalize on the strengths of each in the appropriate lifecycle phase, while balancing technical, schedule and cost risks. Figure 1.0 illustrates the overall hybrid approach for the CCP acquisition strategy.

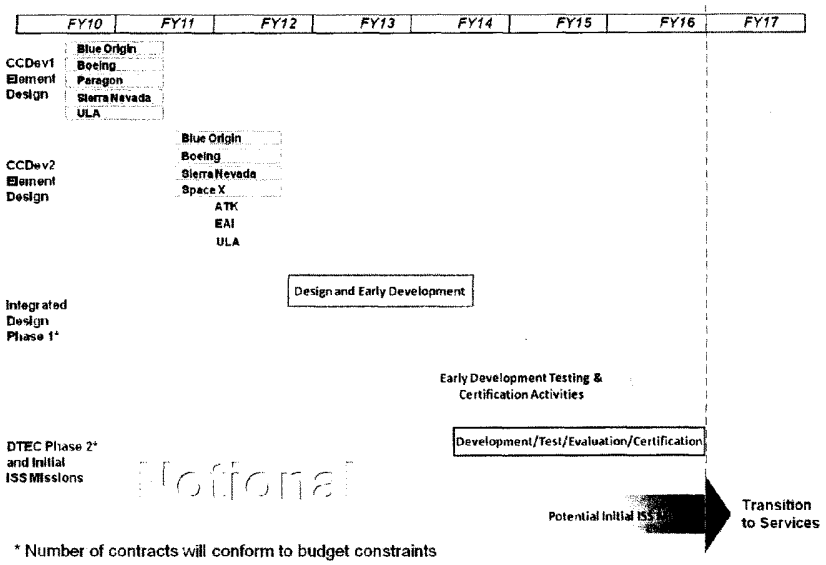


Figure 1.0 – Commercial Crew Acquisition Roadmap

CCP's acquisition approach focuses on reducing the risk and uncertainty of the development cycle and on the incentives provided through competition by separating the design and early development content (Phase 1) from the longer-term Development, Test, Evaluation, and Certification (DTEC) activities (Phase 2). This multi-phased approach provides a shorter period of performance for the Phase 1 contract, thereby limiting the potential financial risk involved in utilizing long periods of performance with multiple commercial partners. Separating the early design from the longer-term development also provides a phased approach to cost assessment and management. The separation between Phase 1 and Phase 2 is distinctly defined to finalize design requirements in Phase 1, prior to a financial commitment to invest in the required capital assets associated with development and testing. Additionally, the approach encourages competition among multiple companies at each stage, which results in lower costs for each lifecycle phase and allows for well-timed incorporation of lessons learned.

On September 19, 2011, NASA released a draft Request for Proposals (RFP) for Phase 1, entitled Commercial Crew Integrated Design Contract (CCIDC), inviting industry to comment on the process. The final CCIDC RFP will incorporate input from industry as appropriate and solicit proposals for a complete end-to-end crew transportation system design, including spacecraft, launch vehicles, launch services, ground and mission operations and recovery. NASA plans to release the final RFP for this effort by the end of 2011. The Agency anticipates that one or more operational CTS will be available for the transportation of astronauts to and from the ISS—as well as the provision of rescue services—by the middle of this decade, assuming that the CCP is funded at the requested level. Competition among multiple partners is a fundamental aspect of the strategy. Competition incentivizes performance, supports cost-effectiveness, and eliminates NASA dependence on a single provider.

Human Rating/Safety

The commercial crew program represents a shift in near Earth operations to the private sector, freeing NASA (and NASA's limited resources) to pursue other human space flight goals, including utilizing the Space Station and setting out on missions of exploration.

Within this new paradigm, NASA will maintain its stringent safety requirements and standards. We have always used contractors to build our space systems. In these programs, we are planning to use an acquisition approach that will allow the contractors more freedom to pursue cost-effectiveness, but still allow NASA the appropriate level of insight and oversight to ensure that the systems will be safe. Developing crew transportation systems to achieve LEO does not require any significant technological breakthroughs which is a key factor in using a unique insight/oversight approach. We will maintain crew safety by way of a crew transportation system certification, and no system will receive this certification until NASA has confidence that our personnel will be safe.

NASA is committed to managing the requirements, standards, and processes for CTS certification to ensure that commercial missions are held to the same safety standards as Government missions. NASA will be responsible for defining, managing, reviewing and approving certification plans and verification closure of requirements related to CCP missions.

To implement the lessons learned from Apollo, Challenger, and Columbia relative to the independent oversight of design, test and certification, CCP will map program processes to the Agency's programmatic guidelines for all NASA spaceflight programs (NASA Procedural Requirements 7120.5, NASA Space Flight Program and Project Management Requirements) while working to minimize bureaucratic hurdles. These processes will include independent review of the commercial providers' performance of key milestones and major technical risks to crew safety. NASA CTS certification will evaluate and assure that the commercial provider's CTS design and implementation can safely conduct the required crew transportation mission. NASA CTS certification includes evaluation of design features and capabilities that accommodate human interaction with the CTS to enhance overall safety and mission success. NASA, through our CTS certification process, is fully accountable for the safety of the NASA crew on CCP missions.

The underpinning of the certification process is the CTS requirements. To date, NASA's CTS requirements have matured considerably. On May 21, 2010, NASA released its first version of commercial human rating requirements to industry in a document titled *Commercial Human Rating Plan (CHRP)*. Through a Request for Information, NASA received extensive and valuable feedback on the CHRP and in-

corporated that feedback, along with refined NASA understanding and planning, into the preparation of the next release of the requirements.

In response to the release of CHRP, industry identified that there was a lack of clarity about the Agency's approach to certifying commercial transportation systems. As a result, NASA released the *Commercial Crew Transportation System Requirements for NASA LEO Missions* to the public on December 10, 2010. This document provides requirements, standards and processes that will be applied to any NASA or NASA-sponsored commercial crew transportation mission to LEO.

CCP currently is refining the requirements identified in the *Commercial Crew Transportation System Requirements for NASA LEO Missions* into several documents to clearly communicate NASA's requirements, standards, and processes for CTS certification. The clarification provided by these documents will allow NASA and industry to ensure all necessary requirements, standards, and processes are met by commercial partners to safely transport NASA and NASA-sponsored crewmembers to the ISS. CCP refers to the program-level requirements as the "1100-series" documents, which are depicted in Figure 2.0. The initial public release of a subset of the program-level requirements was accomplished on October 25, 2010, along with the announcement for CCDev 2.

The second release of the 1100-series documents to industry occurred on April 29, 2011. As a result, all program-level requirements and standards were made available to industry for review and comment. CCP hosted a requirements workshop with industry on May 24–25, 2011 to communicate the intent of the documents, and to continue a dialogue with industry with respect to the documents.

NASA provided a third release of the 1100-series documents in conjunction with the draft Request for Proposals (RFP) for the Integrated Design Contracts on September 19, 2011, followed by another requirements workshop with industry on October 4, 2011. Baseline versions of the 1100-series documents are expected to be released to industry in December 2011 in conjunction with the final RFP for the Integrated Design contracts.

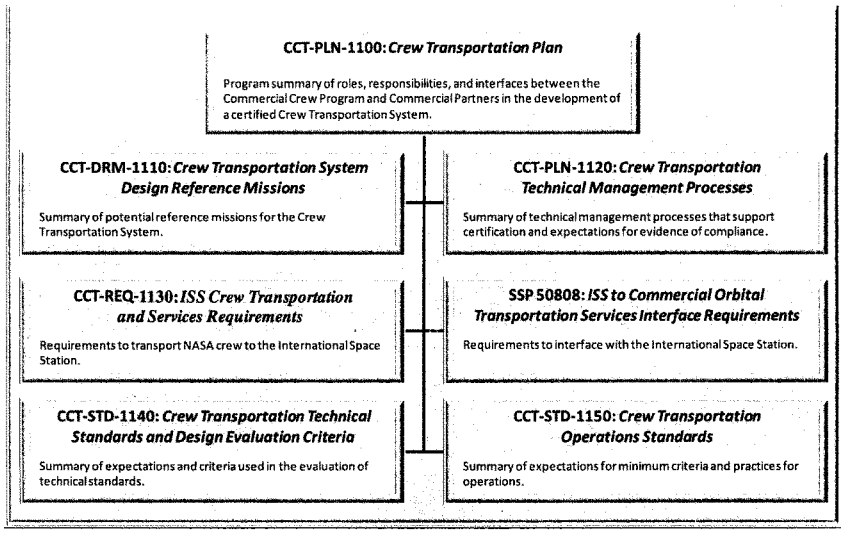


Figure 2.0 – 1100-Series Documentation

As an additional "check and balance" in the area of safety, all CCP activities will be subject to evaluation by organizations independent of and funded separately from CCP, including the NASA Safety and Mission Assurance independent technical authority, the NASA Space Flight Safety Panel which is chaired by a member of the Astronaut Office, and the NASA Aerospace Safety Advisory Panel.

Coordination with the Federal Aviation Administration (FAA)

Both NASA and the FAA envision a state where the FAA licenses commercial human spaceflights provided by a robust industry, from which NASA and the private sector can purchase transportation services. The requirements and processes of these separate agencies must be carefully coordinated and aligned to assure that both Agencies' roles are accomplished with thoroughness and rigor. At the same time, it will be critical to the success of the industry ventures to minimize the burden of Government requirements and regulations imposed by multiple agencies.

The nature of the FAA involvement in NASA's commercial crew activities will vary through the development and operation of each potential flight system. NASA will establish initial certification and operations requirements for the services it wishes to acquire from commercial providers. NASA will partner with the FAA for the purposes of determining common standards and uniform processes to ensure both public safety and protection of crews and spaceflight participants for the NASA-sponsored missions. NASA and the FAA will work towards minimizing the duplication of requirements, developing a streamlined process and addressing indemnification issues.

This will be accomplished by clearly defining roles and responsibilities of each Agency, sharing relevant data and jointly performing assessments to enable the commercial partner to be successful in support of NASA-sponsored missions and non-NASA commercial human spaceflight missions. NASA and the FAA are in the process of documenting agreements that solidify each Agency's commitment to this partnership.

Budget and Recent Accomplishments

NASA has been told consistently by a broad range of potential providers that private sector partners expect to be able to achieve the capability to provide commercial spaceflight services to the ISS within 3–5 years from initial development start. NASA's FY 2012 budget request of $850 million for CCP would provide that initial start in FY 2012 for the development of commercial crew transportation systems which NASA believes would enable services to ISS to be possible in the 2016 timeframe. A reduction in funding from the President's request could significantly impact the program's schedule, risk posture, and acquisition strategy. NASA's initial analysis shows that a FY 2012 funding level of $500 million (consistent with the 2010 NASA Authorization Act) would delay initial capability to ISS to 2017, assuming additional funding is available in the out-years. During that roughly one-year period of delay, NASA would be paying approximately $480M to Russia for crew transportation services. NASA remains concerned about potential reductions to the CCP budget and the anticipated schedule delays and additional costs that they will cause. NASA therefore requests sufficient funding for the CCP to avoid delaying the development of U.S. crew transport capabilities and lengthening the period during which the United States will need to pay Russia to transport crew to the Space Station.

It is worth noting that subsequent to the passage and signing of the 2010 NASA Authorization Act in October 2010, several milestones or similarly important events have occurred which shed new light on the importance, viability, and criticality of NASA's commercial crew efforts.

In April 2011, NASA completed its CCDev agreements with five industry partners. These agreements yielded significant progress on multiple commercial crew transportation concepts for a relatively modest $50 million investment from NASA. Under CCDev, U.S. private industry was able to mature long-lead capabilities that accelerated commercial crew transportation concepts.

As part of CCDev, NASA received and reviewed over 20 proposals from U.S. companies, ultimately making four awards in April 2011. NASA was very impressed with the quality of the proposals which suggested that, given the right investment and appropriate schedule, multiple U.S. companies could develop safe, reliable, and cost effective commercial CTS.

n December 2010, the SpaceX Falcon 9 rocket successfully launched for the second time and the accompanying Dragon spacecraft successfully orbited the Earth and safely returned to the Pacific Ocean. This achievement helps demonstrate the viabil-

ity of the Government/private sector partnerships like the one envisioned for commercial crew and provided further evidence that innovative approaches to spacecraft development efforts can be successful, and considerably less expensive than traditional NASA procurements. However, significant work still remains for delivery of cargo to ISS. The commercial companies are continuing to make sound progress in these activities. I expect to see cargo demonstrations in the next several months.

Lastly, on August 24, 2011, Russia's Progress 44 cargo vessel crashed in Siberia after the third stage of its Soyuz rocket failed. That rocket is similar to the one NASA depends on to transport astronauts to the ISS. A Russian commission recently pinpointed the Soyuz problem as a quality-control issue, not a major design flaw. NASA concurs with that assessment. However, the failure emphasized the need to have a robust capability to transport and provide rescue services for our ISS astronauts. Currently, we have three systems to carry cargo to the ISS, and that number will soon expand to five when Orbital Sciences and SpaceX are successful in completing their systems. However, we only have one system to rely on, the Russian Soyuz, to transport and provide rescue services for our ISS astronauts. If that system is unavailable for any reason for a significant length of time, there can be serious impacts to the productivity of the ISS.

Challenges

Currently, the biggest challenge confronting commercial crew developers as they attempt to develop and demonstrate their systems is financial. This challenge has been consistently cited as the top risk to commercial crew development and NASA's financial commitment is critical to mitigating this risk. For example, in the fall of 2009, the Augustine Report concluded, ".unless NASA creates significant incentives for the development of the [commercial crew] capsule, the service is unlikely to be developed on a purely commercial basis."

NASA's CCP is designed to reduce the risk for private industry by providing significant financial (and technical) assistance for the development of these systems. NASA believes that by providing both assistance in the system development and demand for the service, the "business case" for commercial human spaceflight providers can close for one or more U.S. aerospace companies in a manner that also yields a safe and cost-effective capability for meeting NASA's crew transportation needs.

For these reasons and the timing issues discussed earlier, it is important that the Congress provide robust funding for NASA's commercial crew initiative. This political and financial commitment from the Congress will also reduce the risk for private industry. This Congressional support will support industry in obtaining investment capital above the amount provided by NASA.

In addition to financial challenges, each of the commercial crew developers has unique technical challenges associated with its system. Given NASA's current understanding of the state of the commercial crew development efforts, the Agency is confident that the commercial crew developers can overcome these challenges. However, in order to mitigate the risk associated with technical challenges, NASA plans to support multiple commercial providers, thereby insulating the Agency in the event a commercial provider cannot complete its development effort. In addition, NASA plans to be fully supportive of in the commercial development activities, providing technical assistance, lessons learned, and past experience and knowledge in the area of human spaceflight development and operations.

A final challenge is balancing the need for NASA involvement in order to obtain a safe and reliable system and allowing the providers the freedom to seek innovative and cost effective solutions. Striking the right balance will be key to successful and timely delivery of the crew transportation systems.

Conclusion

The Commercial Crew Program has great promise, but also some significant challenges ahead. Human spaceflight is a very difficult endeavor, and our industry partners will have the responsibility for the full end-to-end system.

We cannot guarantee their success; however, we can structure an approach that provides the highest probability of success. I believe the approach outlined by NASA provides a solid path for developing and acquiring crew transportation services in a manner that is cost effective, and provides for crew safety. We need your support to provide the funding required for this effort.

In July the Space Shuttle Atlantis rolled to "wheels stop" signifying the end of Space Shuttle operations. But, it also signaled the end for now of the ability of the U.S. to transport its astronauts into space, leaving the Nation dependent on the

Russian Soyuz for crew transportation to the ISS. The CCP seeks to ensure that American companies will transport our crews to the ISS by mid-decade and that aerospace jobs and taxpayer dollars remain here in America.

The CCP is the Nation's primary strategy for ending sole reliance on the Russians for crew transportation capability to the Space Station. Private enterprise and affordable commercial operations in LEO will enable a truly sustainable step in our expansion into space-a robust, vibrant, commercial enterprise with many providers and a wide range of private and public users will enable U.S. industry to support NASA—and other Government and commercial users—safely, reliably, and at a lower cost. This is the ultimate goal—one that I believe unites all of us.

Mr. Chairman, I would be happy to respond to any question you or the other Members of the Committee may have.

Chairman HALL. All right. And I thank you. And Members, the two Members that are here know very well, it was three Members. I am sorry. Welcome—that we have a five minute limit on our questions. Let us try our best to stay with it and I will try to set the first record for it myself. I will ask some questions.

My first question is developing any new systems typically takes a lot longer than expected. We know that; we have watched that happen. I know you all have seen it. My question is does NASA plan to negotiate the purchase of additional Soyuz seats that might be necessary in 2016 and 2017 and they are talking about 2020? We don't know what is going to happen between now and then. There has been suggestions that we can accelerate the action prior to that time and then a lot of people think when we had the three birds we had, we ought to rob from two of them and still be flying that one. So there is a lot of arguments pro and con, but we have to face the facts and face what funds are going to be available, and I think it is a shame. As important as NASA is and as important as the space program is that we have less than half a percent of the whole dang budget of the entire Congress when really we are a national defense. We may be defending the next war out of space. It is important, I think, that the people that set the budget really realize this.

The question is whether or not NASA plans to negotiate the purchase of additional seats, and a related question, what would be the impact on the International Space Station if Congress fails to extend the Iran, North Korea, Syria Non-Proliferation Act? And that is a general act that prohibits any American government from purchasing from Russia, but we also have an exception to it called INKSNA that allows them to do it. And you all are familiar with that and you know how to work that and work around it. What are you going to do if we fail to extend that act and the exception?

Mr. GERSTENMAIER. Okay. First of all, we have purchased all the seats from Russia that we can under the existing exemption to the act. So in other words, we have purchased all the things we can up to the period where we will need an exception to the Iran, North Korea, Syria Non-Proliferation Act if we are going to do any additional purchases.

At this time, I think it is too early to say exactly whether we are going to make those purchases or not with Russia. We need to start into this program, see what funding levels we get, see how good of progress these commercial companies can make. As you heard in the previous session, they think they can do better than the dates that I read to you in my opening statement, so we will let them

go ahead and progress through and see and in the next year or so we will see———

Chairman HALL. Now, them, who are you talking about?

Mr. GERSTENMAIER. The commercial companies.

Chairman HALL. All right.

Mr. GERSTENMAIER. The commercial companies look like they can provide earlier dates than what I verbally just read to you. So we will see what happens in the next year, how much progress they make, how well we do on issuing the contracts, and then we will make the decision on what the right risk posture is, should we purchase additional seats from Russia. In the meantime, we are going to have to pursue some relief to the Iran, North Korea, Syria Non-Proliferation Act. We are working that through the Administration now to see what needs to be done there. We think we need an exemption to that even for basic sustaining engineering onboard space station, independent of transportation. So we are starting to do that planning now and I would say we are probably about a year away before we are ready to answer the question that you asked, whether we will make additional purchases.

Chairman HALL. And you think the exception would fall right in line?

Mr. GERSTENMAIER. We will work to get the exception in place to support our needs for crew transportation.

Chairman HALL. All right. I have a minute and 23 seconds I am going to give back to Mr. Miller for his five minutes. You can have my minute and 20 seconds.

Mr. MILLER. Six minutes and 23 seconds?

Chairman HALL. Yes, sir.

Mr. MILLER. That is exceptionally generous, Mr. Chairman.

Mr. Gerstenmaier, in the past, we have paid all the costs of developing human space systems and we have owned them. To paraphrase Ronald Reagan on the subject of the Panama Canal, we bought it, we paid for it, it was ours, and we kept it. In your testimony today you say that the reason to go to commercial firms is to free up money to do other things, but I really have some questions about how that math works. It does appear that we are paying the Soviets—no longer the Soviets—the Russians about $62 million per seat per flight. That is right, isn't it?

Mr. GERSTENMAIER. That is correct.

Mr. MILLER. Okay. And we are presumably—you kept using the term companies but we are probably going to only have one contractor for this, right?

Mr. GERSTENMAIER. Again, we need to go through the acquisition process and do the awarding process and we can see based on what proposals we get how many contracts we can carry through this process. So there may be an option of carrying more than one contractor through this process. We will see once we start getting responses to our proposals that we have put out for them to evaluate.

Mr. MILLER. Okay. The estimates are that they will pay some of the costs, whoever we have a contract with, and it is still hard to imagine that we are going to have two or three primes. I mean we are going to have just one company that we deal with in buying seats, right?

Mr. GERSTENMAIER. Again, I think it is a little early to speculate on that. We have a two-phase procurement where the first portion of the procurement would essentially put the vehicle design in place———

Mr. MILLER. Right.

Mr. GERSTENMAIER. —and we would like to make—drop the request for proposal in the middle of December of this year for that activity. Then, there is a second phase where we do demonstration phases and then we finally go to a service phase at the end. That service phase could be one. Again, it depends. You heard in the earlier———

Mr. MILLER. Okay.

Mr. GERSTENMAIER. —hearing that there may be a market out there that is larger. It is up to these companies, the commercial companies to see if there is a larger market, and if there is, we may be able to choose more than one company. So the answer is, I think, it is too early to say definitely we are going to be down to only one provider.

Mr. MILLER. All right. In terms of developing the system, though, they may pay something but we are going to pay 90—probably 90 cents on the dollar and that is going to end up being around $6 billion. Is that correct?

Mr. GERSTENMAIER. Again, the 90 cents on the dollar discussion appeared from the previous hearing to be different. And you can go back and look at what each individual company said their contributions were, but I think they varied off of that.

Mr. MILLER. Okay, but we think our part is going to be about $6 billion. Is that correct?

Mr. GERSTENMAIER. We are estimating somewhere between $4 and $6 billion.

Mr. MILLER. Okay. And we think that we will end up needing about 40 seats, eight to ten missions to the space station with four astronauts on each, a maximum of about 40 seats, and then we will also be charged presumably per seat at the time. This is just development costs is four to six billion and then we will also have to pay them per seat to go there, isn't that right?

Mr. GERSTENMAIER. Yes, there will be some additional cost for the actual transportation services we———

Mr. MILLER. Any notion at all what that might be, any clue?

Mr. GERSTENMAIER. Well, we think it will be obviously less than what the Soyuz seat price is today.

Mr. MILLER. Okay. More than a bus ticket, less than Soyuz. Have you considered whether we will likely be requested or actually demanded by the companies we deal with that we indemnify them for any liability?

Mr. GERSTENMAIER. I think that is one of the key issues we need to work with the companies and go through in this process. The amount and specific details of the indemnification needs to be worked out with the companies.

Mr. MILLER. Well, there probably will be at least some kind of indemnity?

Mr. GERSTENMAIER. There will be some indemnification.

Mr. MILLER. Okay. It certainly appears that we are paying a lot more per seat than we are paying the Russians now. Is that math wrong?

Mr. GERSTENMAIER. Again, we need to see the actual proposals from the companies to make that statement. In our estimates, we think we can equal the Soyuz seat price or be slightly better than the Soyuz seat price, but we need to see the actual proposals and actually see the concepts get fleshed out by the companies.

Mr. MILLER. And when it comes time to negotiate the per-seat flight, you really think there is a possibility of having more than one company we would negotiate with so there might actually be a market? There might actually be competition? That is a little difficult to imagine but———

Mr. GERSTENMAIER. It is difficult for me to speculate on that one way or the other. I think I would wait until we get a little bit further down the process, see if the market starts maturing as some of the commercial companies talked about in the previous hearing, and then we can make some definitive statement.

Mr. MILLER. Well, with the minute and 33 seconds that Chairman Hall yielded to me, Mr. Martin, have you looked at those numbers and does this appear to be a good deal or how does this compare to the deal we have with the Russians now to pay them $62 million per seat?

Mr. MARTIN. We have not looked at those numbers yet. There are still far too many unknowns with respect to firm fixed requirements and time frames and, importantly, external funding. So we have not looked at those numbers yet.

Mr. MILLER. Okay. Have any of my questions been misdirected? Is there anything in the math that I have laid out that has been incorrect? I mean it certainly sounds like this is going to be a lot more expensive to build a space system for a private contractor who will then own it or pay 90 cents on the dollar, whatever it is, and then contract with them and pay them to transport astronauts. It sounds like it is a lot more expensive than the deal we have now.

Mr. MARTIN. I am going to defer to my colleague here, I am a lawyer but my understanding is that, yes, one of the objectives of course is to get NASA astronauts to the International Space Station, but under the Space Act Agreement was also want to foster this commercial space market. So there is at least two broad objectives in NASA's moving forward here.

Mr. MILLER. Okay. Mr. Chairman, I think I have used my five minutes and your minute and 43 seconds.

Chairman HALL. All right. At this time, I recognize Mr. Rohrabacher, the gentleman from California.

Mr. ROHRABACHER. Thank you very much, Mr. Chairman.

Chairman HALL. Five full minutes.

Mr. ROHRABACHER. Okay. All right. Let us just note that the testimony we just heard indicated that there had been major investment of money in the private sector and that if we can have up to a billion dollars of private sector money invested in space technology development, that is a good thing. That is a very good thing. And it is bound to have a positive result than not having that $1 billion in private money being used for space-based technology development. And I will just note SpaceX, in answer to the question

to my colleague, suggested that they had put in $500 million in development of their Falcon System and only 300 of that—only $300 million came from the government. So SpaceX was actually putting in several hundred million dollars more than what the government actually put into this. That is a good thing that we have a private sector company putting in $500 million in developing a new type of space transportation systems.

So I would suggest that not only in the end by taking this approach. Had NASA been only totally in charge of this goal—of achieving this goal rather than trying to encourage the private sector companies, the major question we have is would that have cost the people, taxpayers, more than what in the end it will cost them when one of these companies wins the competition. Do you have any thoughts on that, either one of you?

Mr. GERSTENMAIER. Again, I think we have been able to use the private company investment very effectively to leverage the NASA investment to get a substantial amount of technology and research and activities done. So I think, so far, it has been a very good process for us in terms of getting return on their investment.

Mr. ROHRABACHER. Yeah. And in the end we hope we will have a product that it will cost less than what Soyuz or at least equal to what Soyuz is offering today and much less than if this was simply a NASA project that was being done in-house with NASA. So at a time when we have $1.5 trillion more in federal spending than we have in money coming in, having private sector money invested seems to me to be a very laudable goal.

And I would like to ask for the last two minutes that I have got here, Mr. Martin, in your June report you describe several potential acquisition strategies that NASA could use for the Commercial Crew Program moving forward, including the use of funded Space Act agreements. Could you confirm the finding in your report that while every acquisition strategy has its strengths and weaknesses, which we have just heard, that the SAA's could theoretically be used by providing certification requirements to participating companies in a non-mandatory fashion?

Mr. MARTIN. Yes, sir. I don't believe our report went that far and I think whether or not———

Mr. ROHRABACHER. It did not. I am trying to push it a little farther.

Mr. MARTIN. No, we did not go that far. It really comes down to sort of a procurement law and a legal question, and I think Bill is in a better position, at this particular stage, certainly with the first phase of this next stage in CCDev, perhaps you may have been able to use either acquisition vehicle.

Mr. ROHRABACHER. Right. Well, you said it is a legal requirement from a policy. According to agency policy, NASA may only enter into funded Space Act agreements when its objectives cannot be accomplished through contract, grant, or other agreements. I understand that is the "policy," but legally, this is not a "legal" requirement, is it? It is just the "policy" requirement?

Mr. GERSTENMAIER. My understanding is it is a legal requirement that once we say we need to have a service or we have a requirement for a capability, at that point we need to go into a FAR-type instrument.

Mr. ROHRABACHER. Okay. Is that your understanding, Mr. Martin, a legal requirement versus this is just what the policy is?

Mr. MARTIN. It is.

Mr. ROHRABACHER. Okay. So you agree with that. Thank you very much.

Thank you, Mr. Chairman.

Chairman HALL. The Chair now recognizes the temporary Ranking Member of the Committee, Ms. Donna Edwards, the gentlelady from Maryland.

Ms. EDWARDS. Thank you, Mr. Chairman. And thank you, gentleman, for your testimony. And I apologize; I had to step out just briefly but I did have a chance to read your testimony. I want to go back to the earlier panel because one of the things that I haven't heard, Mr. Gerstenmaier, is whether you all have in your cost estimates factored things—that at least some of the companies have said that the taxpayer is going to have to underwrite—like indemnification. Is that factored into your cost considerations?

Mr. GERSTENMAIER. It is a consideration but it is really difficult to estimate exactly what that cost could be and how that gets accounted in our budgets. So until we get into that portion of negotiation with the individual companies, it is very difficult to estimate. So we have some assumptions based on where we think it is. We think there will be some indemnification required but———

Ms. EDWARDS. But the companies—excuse me. But the companies in their testimony actually said that they can't do this without the taxpayer providing the indemnification. So it would seem to me that sooner rather than later the taxpayer needs to know how much they are going to be on the hook for in the cases of failure.

Let me just go to something else. Also, the companies talked about—Boeing in particular talked about the ownership of intellectual property rights. This is something that has long concerned me that basically taxpayers are underwriting a lot of the early development work where an awful lot of intellectual property assets are acquired and then the taxpayer basically gets no benefit, no real benefit of that bargain. Why is that in taxpayers' interest not to receive at least some portion of the long-term profitability of intellectual property rights?

Mr. GERSTENMAIER. Again, the model is that the companies are going to invest some of their own money in this activity, and as we have heard, varying amounts depending upon the company. And for that investment, the company expects some return on that investment, so they would like———

Ms. EDWARDS. The taxpayer does, too.

Mr. GERSTENMAIER. I agree. And so the return for the taxpayer is we get a service at a lower price. The return for the company is that they have a vehicle which they own which they can then go market to other users that has really brought down the cost of development for the U.S. taxpayer.

Ms. EDWARDS. Right, I have to tell you I am just not actually clear where or who this other market is that somehow is out there. I haven't been convinced at all about this market, and it sounds to me that the companies that were in front of us are presuming that the biggest consumer here is going to be the U.S. taxpayer for our

space program. And so this sort of ephemeral market and consumer out there I don't think has quite materialized enough.

Let me just go to another question. Your Deputy Administrator was recently quoted as saying, "We have an analysis that says we believe we would require $6 billion over 5 years." If you have that analysis, I think it would be helpful for this Committee to see that analysis to know upon which you base that $6 billion over five years. Do you have an analysis?

Mr. GERSTENMAIER. We have the basis for our budget submit and the basis of our estimate. It is roughly a range between 4 and $6 billion.

Ms. EDWARDS. Well, what is the analysis that the Deputy Administrator was referring to?

Mr. GERSTENMAIER. It is a portion of that same analysis, but the way it is going to work is when we actually get the proposals from the contractors next year, we can then really definitize that and we can show you a much more definitive budget. The problem with this acquisition is there is a lot of uncertainty of how much the companies will invest in their piece that we don't know right now. We have some other issues to work out with them in terms of those prices. So we have estimates, we have a basis and a model that we have based our budgeting on, but we need to get that data from the companies to actually get more of a definitized model. So we have———

Ms. EDWARDS. For those of us who do numbers, can you show us the basis of your analysis?

Mr. GERSTENMAIER. Yeah, we can—it will be a range and you can see the range.

Ms. EDWARDS. No, I guess I am trying to figure out all of your underlying assumptions in making the analysis. I mean if your Deputy Administrator is going to say definitively that we are going to need $6 billion over five years, I kind of want to know where that is coming from.

Mr. GERSTENMAIER. We can show you the basis for that estimate.

Ms. EDWARDS. And then, Mr. Martin, how well do you have an understanding of NASA's budget and the schedule estimates for the Commercial Crew Development Program?

Mr. MARTIN. We have not—in preparing our June audit report on the status commercial crew challenges, we did not have access to those. We did not analyze those documents.

Ms. EDWARDS. So NASA hasn't given you an analysis that provides the basis for the estimates that they are making?

Mr. MARTIN. They have not but they wouldn't in normal course.

Ms. EDWARDS. Would you ask for one?

Mr. MARTIN. I will.

Ms. EDWARDS. Thank you. And then lastly, I just want to go to this point. It seems to me that we are running on a course of eventually the taxpayer subsidizing a monopoly, and my worry about that is that in subsidizing a monopoly, we will end up footing an even bigger bill than we can anticipate in the beginning because there will be no other, you know, I don't know, horse in the race, you name your analogy. And so how does—how do you, Mr. Gerstenmaier, then estimate what the overall cost to taxpayers is

going to be in terms of subsidizing essentially one entrant, maybe you say another, into this program?

Mr. GERSTENMAIER. We tried to structure the acquisition approach in two phases. The first phase of the acquisition approach is essentially where we have the companies work on developing the design, and that means we get all the requirements in place, we see how well they understand our safety requirements, we see how well they can respond to our relaxed contracting requirements, we can actually see company performance with some milestones and development tests during that phase, and then we can enter into the second phase. So we can limit our exposure by doing this as a two-phase procurement so we can see the first portion of the procurement activities and see how well it progresses, see if we are making significant progress, see if these estimates that we put together for our budget hold up. If they do, then we can proceed into the second phase. If we see through this first phase something just doesn't look right, it is totally different than we have got, we can adapt to that and then move forward to the next phase. So therefore we can———

Ms. EDWARDS. Just as you close because I know the Chairman———

Mr. GERSTENMAIER. —minimize the risk to the taxpayer.

Ms. EDWARDS. Thank you. Just one last question and just a yes or no answer. Have any of the companies that were here before us ever provided safe crew transport?

Mr. GERSTENMAIER. I guess if you—under this model, no, but if you look at the space shuttle and———

Ms. EDWARDS. Have any of the companies that were here that we have invested in at this point ever provided that? NASA has but these companies haven't right?

Mr. GERSTENMAIER. Well, Boeing did the work in cooperation with NASA to develop the space shuttle which delivered crew to space.

Chairman HALL. Ms. Edwards did a good job, but golly, I miss Ms. Johnson.

Mr. Palazzo, I recognize you for five minutes.

Mr. PALAZZO. Thank you, Mr. Chairman.

Mr. Gerstenmaier, you were developing an acquisition strategy for commercial crew and I think you were using the $850 million mark. What would you do differently if you have less than that, or more specifically, based on the $500 million that the Senate is pushing?

Mr. GERSTENMAIER. Again, based on our models and our internal estimates which have some softness in them because this is a new approach for procurement for us, if we ended up with $500 million in 2012, as long as we have got some additional funding in the out years above the levels that we put in our budget request, we think that would delay the commercial crew service to space station by about 1 year.

Mr. PALAZZO. What is the total estimated cost of taxpayer dollars that NASA is committed to spending on each current commercial contractor?

Mr. GERSTENMAIER. We have not broken it out by individual contractor. We have the total budget estimate that I described before of roughly four to six billion.

Mr. PALAZZO. Do you have any legitimate studies that provide a realistic picture of the commercial market for human space flight activities that will exist in the next five years?

Mr. GERSTENMAIER. We have in our report which we provided to Congress there is a wide range of potential activities that sit out there or potential market that sits out there in the future. There is a lot of uncertainty in that market, and I think again you can—as you heard in your previous panel—they can better describe what that market is than I can.

Mr. PALAZZO. How many commercial crew providers can NASA support if the commercial market fails to materialize?

Mr. GERSTENMAIER. Again, we will see what the cost is for those services, and depending upon the cost for those services, we could potentially support more than one but we need to see what the actual cost of the services is and then we will determine what that is—what we can afford in terms of number of providers.

Mr. PALAZZO. How many flights per year are you planning to support the space station?

Mr. GERSTENMAIER. It would be roughly two flights per year.

Mr. PALAZZO. Two?

Mr. GERSTENMAIER. And we could change that model if the research demand changes and someone wants some other activities, but right now, that is our basic plan is two.

Mr. PALAZZO. What is your estimated cost per flight once the development stage is completed?

Mr. GERSTENMAIER. Again, we would look at it as equal to or less than what we would be paying for Soyuz at that time.

Mr. PALAZZO. Some———

Mr. GERSTENMAIER. Roughly $480 million or so.

Mr. PALAZZO. How much would that come down per astronaut since that seems to be the common way of looking at it?

Mr. GERSTENMAIER. Roughly $80 million per crew seat.

Mr. PALAZZO. Okay.

Mr. GERSTENMAIER. Six seats per year, $480 million total per year.

Mr. PALAZZO. All right. Well, thank you for your testimony, and I yield back.

Chairman HALL. I thank the gentleman, and the round of questions are completed. And I really thank both of you. You are very important, you are knowledgeable, and thank you for sharing that knowledge with us. Time and time again we have had you before.

Members of the Committee have additional questions of witnesses, we will ask the witnesses to respond to those in writing. They might and we will send them to you. The record will remain open for two weeks for additional comments from Members, and witnesses are excused.

And this hearing is adjourned.

[Whereupon, at 12:59 p.m., the Committee was adjourned.]

Appendix I:

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Mr. John Elbon, Vice President and General Manager for Space Exploration, The Boeing Company, Houston, TX

Questions submitted by Chairman Ralph Hall

Q1. How confident are you about NASA's and FAA's ability to coordinate their requirements for commercial crew launches? Have you seen any evidence yet that the two agencies are attempting to define roles and responsibilities, and to minimize overlap?

A1. NASA and the FAA both have key roles in establishing requirements for commercial crew launches, and have demonstrated willingness to work together to define the requirements. The regulatory body controlling NASA commercial crew flights to the ISS has not been definitively established to our understanding, but NASA and the FAA are working closely to finalize those details. Commercial crew flights in support of customers other than NASA will need to be regulated by the FAA. It is important for Congress to provide the FAA the ability to establish regulations to the existing Part 400 in support of this emerging market. Earlier regulatory ability will play a key role in stimulating the commercial space market in several ways. Regulations will help the insurance industry baseline safety for underwriting, resulting in more affordable insurance premiums. Regulations will also provide a level playing field, ensuring that all potential providers and operators duly consider safety concerns. A lack of safety regulations also increases business risk for all participants. An accident prior to regulation enforcement could produce three negative economic drivers: increased insurance costs, a pendulum swing to over-regulate, and lessened demand due to simple fear.

Q2. Launch abort systems are one of the most critical technically challenging features to design, integrate and test. What type of launch abort system do you intend to build into your crew system, and how mature is the design? Do you intend to demonstrate it in a relevant launch environment?

A2. Boeing's CST–100 capsule utilizes a "Pusher type" launch abort system (LAS) with four 40,700-lb thrust launch abort engines which are derived from the Atlas II sustainer engines. Our LAS design ensures a controllable, stable abort from pad through orbit insertion with no "black zones," meeting or exceeding all requirements for separation. During CCDev-2, we performed three full duration LAE development tests. During the future phases of the program, we plan to perform additional single engine hot-fire tests prior to full-up Service Module cold flow tests and hot fire tests. These tests precede a pad abort test that is similar in nature and uses the same test stand as the abort test conducted for the Orion spacecraft.

Questions submitted by Ranking Member Eddie Bernice Johnson

Q1. NASA's plan requires the development and certification of the commercial crew systems to occur within a tight timeline, requires the commercial systems to capable of safe and reliable flight operations by 2016, makes use of new and unproven government-industry development and safety approaches, and has development and operations costs that are still unknown. In that regard, please provide the following questions:

- *What is the evidence that you believe provides the justification for Congress to invest in this commercial crew initiative, and*
- *What your company realistically would require from the U.S. government to make this initiative a success.*

A1. The government-industry partnership on Commercial Crew has been highly successful as demonstrated by Boeing's ability to complete a system preliminary design review in March 2012, less than two years from program start, with $120M of government funding. This is significantly faster and less expensive than traditional programs. In addition, we are designing the system with a firm understanding of NASA's safety and certification requirements, based on five decades of building and operating HSF systems. Boeing's CST–100 will provide safe, reliable, and affordable domestic transportation capability to ensure the full utilization of the ISS. This affordable transportation capability will also allow additional NASA resources to be applied to exploration beyond LEO with the Space Launch System and Orion vehicles. The commitment demonstrated by Congress and NASA to support

the infrastructure development is critical to support the emergence of the commercial space market. Boeing, in partnership with NASA, will deliver a safe, reliable, and affordable commercial crew system. Boeing has invested a significant amount prior to and during the performance of CCDEV, and will continue to invest throughout the development phase.

Q2. What is your understanding of how third-party liability and indemnification will be addressed for both launch and reentry and for on-orbit operations of any commercial crew transportation system used for NASA ISS servicing:

- *How important an issue is liability and indemnification to any decision your company might make to enter into a Phase 1 or Phase 2 development contract with NASA for commercial crew systems, or to enter into a service contract with NASA to transport astronauts to the ISS?*
- *Do you plan to purchase insurance for your systems as part of your business plan, and how confident are you that adequate insurance coverage will be available privately? If it isn't, what do you plan to do?*

A2. There are two viable paths for liability protection in support of commercial crew launches to the ISS. If NASA is the final regulatory authority, they could offer indemnity protection for the launch, on-orbit, and re-entry phases of these launches. However, if the FAA is determined to be the regulatory authority for launches to the ISS, the launch and re-entry phases would be licensed through the CSLA. In this situation, insurance would be procured up to the maximum probable loss determination, and additional liability would be covered through the congressionally approved indemnity ceiling. Damage to the ISS would not be insurable, and adequate cross-waivers would need to be provided by NASA through their planned certification approach.

FAA, COMSTAC and industry have been working together on defining an approach for addressing third-party liability for both launch and reentry phases. FAA has proposed an extension to the Commercial Space Launch Act (CSLA) with informed consent as the path to limit liability. Boeing will require adequate cross waivers of liability prior to docking with ISS. For areas of risk not addressed by legislative limits of liability or indemnification, Boeing has included insurance protection in our cost estimates and business plan.

Q3. During the hearing, you testified that your company could provide commercial crew transportation services within the 2015–2016 timeframe. Please provide 1) the assumptions behind the date, including a) the magnitude and timing of funding from NASA, b) the timeline assumed for development, integration, testing, and certification, and c) the number of certification flights you are assuming will be required.

A3. The details of the Boeing plan for completing development of our Commercial Crew Transportation System—including assumptions, magnitude and timing of NASA funding, timeline, and certification approach—represent our proposal to NASA in response to the Commercial Crew Integrated Capability (CCiCAP) announcement for proposals. This is an ongoing competitive procurement, with awards expected July/August 2012. The CCiCAP AFP projected maximum awards during the 21-month base period of $300–$500 million. This funding level is below the funding level required to support a 2015 crewed test flight. However, if NASA is able to provide additional funding to Boeing during this phase, the launch date could move up to as early as 2015. The total funding required for the development and certification of the Boeing system is approximately $2 billion. This includes extensive qualification testing on the service module, structural test article, and qualification test articles. In addition, the cost includes a pad abort test, un-crewed orbital flight test, and a crewed flight test. Note that Boeing's system cost above is for the development of the entire commercial crew mission capability, which includes ground operations, mission operations, crew training, and the launch vehicles to support the flight tests.

Q4. Would you anticipate any additional capacity on CST–100 flights after taking into account NASA's crew requirements on ISS crew rotations?

- *How will that overcapacity be dealt with?*
- *Will NASA be required to procure the entire spacecraft, or will they be able to just purchase the required number of seats for each flight?*
- *If passengers not paid for by NASA are transported on the flight, how will their stay on the ISS be accommodated and for how long?*
- *Are you assuming the ISS partnership will host the non-NASA spaceflight participants on the ISS?*

- *If you are planning to fly extra passengers on each flight, how do you plan to get them back from the ISS in an emergency if the CST–100 capsule is also supposed to serve as an ISS crew rescue vehicle?*

A4. NASA has identified a transportation requirement for crew and limited cargo. The Boeing CST–100 spacecraft can accommodate up to 7 crew or a combination of crew and cargo. As part of our business plan, we anticipate a market for private space flight participants to travel to ISS, and if NASA were to approve such participation, the resulting revenue could offset the NASA mission cost. NASA could also use the additional cargo capacity available on each flight to support science payloads or logistics requirements. In the event private spaceflight participants were approved for travel to the ISS, it is projected that they would return on the Boeing CST–100 spacecraft that was docked to the ISS, serving as the prior rescue vehicle.

Q5. NASA has proposed that the first phase of its commercial crew procurement—the Integrated Design Contract—be awarded fixed-price contract. From your perspective, is that a manageable approach?

- *How would you plan to balance risk mitigation and flight test programs, which can be expensive, against the need to keep within the contracted-for fixed-price limits?*

A5. NASA has changed its acquisition approach from a FAR-based fixed-price contract to an SAA, which also requires fixed price milestones. Boeing believes that a fixed-price contract is acceptable for this procurement. The design solution is low-risk, benefiting from the incorporation of flight proven hardware previously flown on other Boeing programs, including the X–37, Orbital Express, Space Shuttle, and other programs. Efficient design and manufacturing approaches proven on Boeing commercial and defense programs are being incorporated in the CST–100 design to ensure successful program execution. Our approach has already included numerous risk mitigation hardware development tests to ensure success early in the development phase, significantly reducing the risk of costly redesigns later in the design phase. At Boeing, our brand and our business are fundamentally dependent on the safety of our products. We do not sacrifice safety for cost performance, because there is nothing more costly than an unsafe product. We have demonstrated repeatedly—across a range of commercial and defense aircraft and spacecraft—our ability to develop and manufacture safe and reliable products, and to do so in such a manner as to run a profitable, well-performing business.

Questions submitted Representative Paul Broun

Q1. What obligation does your company have under space act agreements to report anomalies to NASA?

A1. Under the CCDev, CCDev2, and CCiCap space act agreements, NASA embeds a Partner Integration Team with our team for ongoing insight into our development process. NASA has visibility into our tests, demonstrations, and reviews as we are performing them and is aware of the outcomes as they occur.

Q2. What information do you believe your company is obligated to provide NASA about anomalies under a space act agreement?

A2. See response to item 1 above.

Q3. How long after an anomaly is detected, observed, or identified, do you believe your company is obligated to report such an anomaly to NASA under a space act agreement?

A3. See response to item 1 above.

Q4. What obligations does your company have under traditional contracting to report anomalies to NASA?

A4. The planned NASA insight approach is the same, regardless of contracting mechanism. Whether under SAA or FAR-based contract, NASA embeds members of their Partner Integration Team with our team, and they have full visibility into our tests, demonstrations, and reviews as they occur.

Q5. What information do you believe your company is obligated to provide NASA about anomalies under traditional contracting?

A4. See response to item 4 above.

Q6. How long after an anomaly is detected, observed, or identified, do you believe your company is obligated to report such an anomaly to NASA under traditional contracting?

A6. See response to item 4 above.

Q7. What obligations does your company have under the modified FAR acquisition to report anomalies to NASA?

A7. Boeing is unable to answer as NASA did not provide the final terms and conditions for their proposed modified FAR acquisition prior to switching to a space act agreement approach. However, the NASA insight approach, in which the NASA Partner Integration Team has full ongoing insight into our development effort, obviates the need for such reporting as NASA is aware as events emerge.

Q8. What information do you believe your company is obligated to provide NASA about anomalies under a modified FAR acquisition?

A8. See response to item 7 above.

Q9. How long after an anomaly is detected, observed, or identified, do you believe your company is obligated to report such an anomaly to NASA under a modified FAR acquisition?

A9. See response to item 7 above

Questions submitted Representative Jerry Costello:

Q1. NASA's FY 2012 budget request proposes a total of $4.25 billion over five years, or $850 million a year through 2016, to fund the U.S. government's share of commercial crew capabilities development for one or more systems. What do you believe, in terms of a percentage of total development costs, the private sector might realistically contribute?

- *What percentage is your company planning to contribute?*

A1. Boeing has invested significantly over the past five decades as well as directly in the performance of commercial crew development on hardware and technologies that support our offering. We will continue to offer significant investment throughout the development phase. NASA and the Congress have taken a tremendous step to stimulate this emerging market by committing to funding the preponderance of the development cost. Without this commitment, the market would take significantly longer to mature. In addition, the ability to provide a safe, reliable, and affordable domestic transportation capability vital to the ISS would not be available.

Q2. Is private sector investment contingent on additional, non-financial U.S. government support too? If so, what would that support involve?

A2. The support provided by NASA and the Congress to fund the preponderance of the development cost, along with significant industry investment, will ensure the ability of a safe, reliable, and affordable domestic transportation capability to the ISS. In addition, this commitment will allow the stimulation of the commercial space transportation market. The ability of NASA and/or the FAA to regulate these launches will be required prior to the services phase.

Q3. What is your reaction to NASA's proposed approach to human-rating future commercial crew transportation systems? Do you believe NASA's proposed approach will both ensure astronaut safety and facilitate eventual FAA licensing of launches for non-government customers? Are there any changes you would like to see made to the approach?

A3. NASA is applying their considerable experience in human space flight to baseline a set of human rating requirements to ensure crew safety and facilitate FAA licensing for non-government customer launches. Boeing incorporated the NASA requirements into our own design requirements to ensure that our system can achieve NASA and FAA certification. Although Boeing has adopted the NASA human rating requirements in our design, there is no contractual requirement to do so. We don't have insight into other competitors' plans, but we feel it is important that NASA have the ability to contractually levy design requirements in the future to ensure design safety, and an equitable competitive environment.

Q4. During the hearing, you testified about the investment your company is making in commercial crew activities relative to what the government is investing in your program. Do you intend to maintain that percentage should you receive an award for the design and development contracts from NASA? If not, what level

of investment would you anticipate contributing for the design and development contract phase?

A4. Boeing will continue to invest at the previous percentage level, providing NASA evidence at our commitment to provide a safe, reliable, and affordable commercial crew transportation system.

Responses by Mr. Steve Lindsey, Director of Space Exploration, Sierra Nevada Space Systems, Louisville, CO

Questions submitted by Chairman Ralph Hall

Q1. How confident are you about NASA's and FAA's ability to coordinate their requirements for commercial crew launches? Have you seen any evidence yet that the two agencies are attempting to define roles and responsibilities, and to minimize overlap?

A1. Sierra Nevada Corporation is working directly with both NASA and the FAA to coordinate our flight test program, set to begin in 2012. We don't have any direct evidence that the two agencies are defining roles and responsibilities to minimize overlap, but we do know that the FAA has a person directly assigned to NASA's Commercial Crew Program and that they have been working cooperatively on our program. We hope that meeting NASA's defined requirements will also lead to a smooth licensing process through the FAA. This, of course will depend upon close communications, cooperation, and agreement between the FAA and NASA.

Q2. Launch abort systems are one of the most critical and technically challenging features to design, integrate and test. What type of launch abort system do you intend to build into your crew system, and how mature is the design? Do you intend to demonstrate it in a relevant launch environment?

A2. SNC plans to utilize the Atlas V rocket which is well known to both the DoD and NASA as it is their primary launch vehicle for high value payloads. The Atlas V has had 30 flights to date, all successful, and its characteristics are well known. SNC has been working with ULA for over five years studying and demonstrating through testing that our vehicle will not pose any significant challenges. We require no solid boosters which contribute to safety. On board the Sierra Nevada Dream Chaser we use our internally developed hybrid rocket motors as our abort system, which are designed to ensure a runway landing from anywhere along the ascent trajectory. We do not require a separate launch abort system external to the vehicle. These flight-proven rocket motors have already successfully flown into space on Spaceship 1 and the technology has already had over 50 tests to date. We just completed wind tunnel tests further validating positively our ascent models and intend to test our motors during powered flight drop testing. Additionally, prior to our first orbital flight we will demonstrate a powered abort from a simulated launch pad to a runway landing at Edwards Air Force Base as part of an end to end flight test program. We also plan to do an uncrewed autonomous orbital flight where the hybrid motors will again be tested on-orbit prior to the first crewed mission.

Questions submitted by Ranking Member Eddie Bernice Johnson

Q1. NASA's plan requires the development and certification of the commercial crew systems to occur within a tight timeline, requires the commercial systems to be capable of safe and reliable flight operations by 2016, makes use of new and unproven government-industry development and safety approaches, and has development and operations costs that are still unknown. In that regard, please provide the following questions:

- *What is the evidence that you believe provides the justification for Congress to invest in this commercial crew initiative , and*
- *What your company realistically would require from the U.S. Government to make this initiative a success.*

A1. Sierra Nevada Corporation is the ideal partner for NASA to develop a U.S. capability to provide safe, reliable, and cost-effective access to Low Earth Orbit (LEO). We are an experienced systems integrator and a builder of 100% reliable space hardware that meets the goals and objectives of the commercial crew program. Over our 25 years we have been engaged on over 400 space missions and have built over 4,000 systems, subsystems and components all of which have operated successfully on orbit. We successfully completed the first two phases of the NASA commercial crew program by performing extensive risk reduction and building hardware. To date we have completed all our milestones, 12 in total, on time and on budget while providing NASA complete insight and access to our technical program. We have brought together over 12 heritage space companies, three aerospace universities and 7 NASA centers to be part of our program with employment happening in over 10 states, including expected significant growth in Texas where we have opened a new office.

With all of the necessary partnerships, facilities and investment in place, we are ready to take the next step in the development of our integrated crew transportation system. The Dream Chaser Space System is based upon a NASA program called the HL–20 which had over ten years of development, includes the reliable Atlas V launch vehicle which has flown over 30 times, and has ground and mission systems that leverage the known infrastructure of the Kennedy and Johnson Space Centers, including Johnson's Mission Operations Directorate which has successfully controlled and flown almost all of NASA's human spaceflight missions. The Dream Chaser lifting body spacecraft offers significant advantages over capsules including low g reentry, substantial cross range and gentle runway landings. Our goal is to bring the jobs currently being outsourced to the Russian Space Program back to the United States and in doing so continue to drive America technology and manufacturing base forward while creating STEM opportunities for the next generation. Without this effort we are consigned to purchase our space needs from aboard. We realize that these are difficult economic times which are why as a Company we have substantially co-invested alongside of NASA. What we need most from the USG is predictability in the program and support to this mission of returning jobs to the U.S. It is difficult to build on a program that takes years without a commitment. We support this commitment being conditioned on our being able to continue to meet our milestones.

Q2. What is your understanding of how third-party liability and indemnification will be addressed for both launch and reentry and for on-orbit operations of any commercial crew transportation system used for NASA ISS servicing?

- *How important an issue is liability and indemnification to any decision your company might make to enter into a Phase 1 or Phase 2 development contract with NASA for a commercial crew system, or to enter into a service contract with NASA to transport astronauts to the ISS?*
- *Do you plan to purchase insurance for your systems as part of your business plan, and how confident are you that adequate insurance coverage will be available privately? If it isn't, what do you plan to do?*

A2. Per the Commercial Space Launch Amendments Act (CSLAA), all applicants applying for a launch and/or re-entry license from FAA must demonstrate financial responsibility through liability insurance or other means to cover third-party liability as well as damage or loss to Government property. The amount of the liability that has to be covered is determined by the FAA as part of the licensing process and is called the Maximum Probable Loss. We understand that we are responsible for that liability. Currently, there is limited indemnification for license applications received no later than December 31, 2012. Liability and indemnification is a very important issue for all commercial service providers, but we understand that it will take some time to finalize all the related issues, so this would not keep us from proceeding with development contracts with NASA. It will be a factor in our eventual pricing for a service contract since we will have to include the costs for liability insurance for all phases of the service. We do plan to purchase all the necessary insurance as part of our business plan and have had discussions with space insurance brokers and underwriters and believe that insurance coverage will be available privately.

Q3. During the hearing, you testified that your company could provide commercial crew transportation services within the 2015–2016 timeframe. Please provide 1) the assumptions behind that date, including a) the magnitude and timing of funding from NASA, b) the timeline assumed for development, integration, testing and certification, and c) the number of certification flights you are assuming will be required.

A3. As part of the competitive Commercial Crew Integrated Capabilities (CCiCap) proposal due to NASA on March 23, 2012, bidders are required to provide all of the information that is asked in this question as well as to identify the magnitude and timing of the company investment on the program. Since this is a competitive proposal that is still under review we respectfully cannot provide detail to this question at this time. We can however state that we are able to meet or exceed the requirement for flight times and costs as outlined in that RFP and would be available to provide information at a future date.

Q4. Would you anticipate any additional capacity on the Dream Chaser after taking into account NASA's crew requirements to ISS crew rotations?

- *How will that overcapacity be dealt with?*

- *Will NASA be required to procure the entire spacecraft, or will they be able to just purchase the required number of seats for each flight?*
- *If passengers not paid for by NASA are transported on the flight, how will their stay on the ISS be accommodated and for how long?*
- *Are you assuming the ISS partnership will host the non-NASA spaceflight participants on the ISS?*
- *If you are planning to fly extra passengers on each flight, how do you plan to get them back from ISS in an emergency if the Dream Chaser is also supposed to serve as an ISS crew rescue vehicle?*

A4. NASA's stated ISS requirement is to provide transportation to four crewmembers for crew rotation. Sierra Nevada's Dream Chase Space System has a capability for seven seats. The additional three seats can be used in several ways. Those seats can be replaced by equivalent cargo to ISS or used to fly additional ISS crewmembers or payload specialists. Sierra Nevada plans to provide transportation services by the seat, so NASA will not be required to procure the entire spacecraft. We also assume that we are responsible for the logistics associated with any spaceflight participants that are not NASA crewmembers. We will either provide all support for these additional participants, or negotiate support with NASA/ISS, or a combination of the two. Extra passengers will only be flown if the ISS crew rotation model is 'direct handover'—which means there will be a second Dream Chaser already on-orbit. In this case the non-NASA astronauts would only be on the ISS as long as it takes to swap out crews; they would all return to earth with the ISS crewmembers rotating home. In our traffic model, no non-NASA spaceflight participants would spend more than a few days on the ISS.

Q5. NASA has proposed that the first phase of its commercial crew procurement—the Integrated Design Contract—be awarded as a fixed-price contract. From your perspective, is that a manageable approach?

- *How would you plan to balance risk mitigation and flight test programs, which can be expensive, against the need to keep within the contracted-for fixed-price limits?*

A5. SNC believes that our vehicle can be successfully designed, built, tested, and certified within the framework of a fixed-price contract. We have been in the aerospace business for over 25 years and have successfully completed hundreds of fixed price programs. There can be no compromise when it comes to astronaut safety. Of the greatest advantage to us is that a majority of our systems have significant flight heritage. For example the Atlas V, which pricing is known and our environmental systems which are NASA heritage. This provides us with the visibility to more accurately predict our costs. To back this up, SNC has available to it a substantial and existing financial capability which provides ample contingency for future program changes.

Questions submitted by Representative Paul Broun

Q1. What obligation does your company have under space act agreements to report anomalies to NASA?

Q2. What information do you believe your company is obligated to provide NASA about anomalies under a space act agreement?

Q3. How long after an anomaly is detected, observed, or identified, do you believe your company is obligated to report such an anomaly to NASA under a space act agreement?

Q4. What obligation does your company have under traditional contracting to report anomalies to NASA?

Q5. What information do you believe your company is obligated to provide NASA about anomalies under traditional contracting?

Q6. How long after an anomaly is detected, observed, or identified, do you believe your company is obligated to report such an anomaly to NASA under traditional contracting?

Q7. What obligation does your company have under the modified FAR acquisition to report anomalies to NASA?

Q8. What information do you believe your company is obligated to provide NASA about anomalies under a modified FAR acquisition?

Q9. How long after an anomaly is detected, observed, or identified, do you believe your company is obligated to report such an anomaly to NASA under modified FAR acquisition?

A1–9. Sierra Nevada's approach to the NASA's Commercial Crew Program is to be completely transparent, whether we are on a Space Act Agreement or a FAR-based contract. NASA is invited to any and all technical meetings we have, and learns of any anomalies in our technical development as they are happening. This completely honest and open approach enhances the NASA–Sierra Nevada team environment, promotes trust, and ultimately results in a much better product for both Sierra Nevada and NASA. We would expect no difference in dealing with anomalies under any contract type. Our safety program is consistent and is based upon doing what is right for the astronauts and the success of the program. We cannot answer how NASA may have dealt with such issues under a FAR or modified FAR contract as there was not a final RFP that was issued and that is a question better asked to NASA.

Questions submitted by Representative Jerry Costello

Q1. NASA's FY 2012 budget request proposes a total of $4.25 billion over five years, or $850 million a year through 2016, to fund the U.S. government's share of commercial crew capabilities development for one or more systems. What do you believe, in terms of a percentage of total development costs, the private sector might realistically contribute?

- *What percentage is your company planning to contribute?*
- *Is private sector investment contingent on additional, non-financial U.S. government support too? If so, what would that support involve?*

A1. As part of the competitive Commercial Crew Integrated Capabilities (CCiCap) proposal due to NASA on March 23, 2012, bidders are required identify the magnitude and timing for all required NASA funds and all planned company investments both for a base contract period of 21 months, and for full system development through a crewed orbital demonstration flight. The percentage of company investment and how it relates to required NASA funding will be evident in our proposal. As this is in the competitive stage we cannot answer this question, however, we can say that our contribution was significant in the first two phases of the program and, for us, is not expected to be contingent on additional non-financial U.S. government support.

Q2. What is your reaction to NASA's proposed approach to human-rating future commercial crew transportation systems? Do you believe NASA's proposed approach will both ensure astronaut safety and facilitate eventual FAA licensing of launches for non-government customers? Are there any changes you would like to see made to the approach.

A2. SNC believes that NASA's approach to human rating will ensure both astronaut safety and eventual FAA licensing. SNC is designing the Dream Chaser spacecraft to NASA's 1100 and 50808 series requirements—which are the most recent NASA human rating requirements. Meeting these requirements will ensure we have the safest spacecraft possible—they are derived from ISS, Space Shuttle, and Constellation program requirements. FAA licensing should follow if there is tight communications, cooperation, and agreement between NASA's requirements and the FAA's licensing requirements for commercial spacecraft.

Q3. During the hearing, you testified that your company is investing about 40 percent of the cost of your commercial crew activities relative to what the government is investing in your program. Do you intend to maintain that percentage should you receive an award for the design and development contracts from NASA? If not, what level of investment would you anticipate contributing for the design and development contract phase?

A3. The percentage of our company investment and how it relates to required NASA funding will be disclosed in our proposal. As this is in the competitive stage we cannot answer this question at this time.

Responses by Mr. Elon Musk, CEO and Chief Technology Officer, Space Exploration Technologies Corp., Hawthorne, CA

Question Submitted by Chairman Ralph Hall

Q1. How confident are you about NASA's and FAA's ability to coordinate their requirements for commercial crew launches? Have you seen any evidence yet that the two agencies are attempting to define roles and responsibilities, and to minimize overlap?

A1. SpaceX is confident that NASA and FAA will effectively coordinate their requirements for commercial crew launches. As you know, SpaceX previously secured FAA licensing for launch and reentry under the NASA Commercial Orbital Transportation Services (COTS) program. For Commercial Crew, we understand that NASA and FAA are in ongoing discussions to ensure that FAA regulations support NASA requirements and that duplication of efforts is minimal. The divisions of labor between NASA and FAA are clear: since NASA is both the leading federal agency for human spaceflight and the end user of the Commercial Crew Program, NASA should set requirements for human spaceflight systems. FAA should retain its current regulatory scope of protecting public safety during launch and reentry using its authority under the Commercial Space Launch Act (CSLA) of 1984, as amended.

NASA and FAA collaboration for future commercial crew missions is already underway. A NASA employee from the Commercial Crew Program office is on a rotational assignment at FAA headquarters. Similarly, a FAA representative is assigned to the Commercial Crew Program office at NASA's Kennedy Space Center. NASA is supporting FAA definition of regulations for crew and participant safety and FAA is participating in CCP safety certification requirements development. Both Agencies are ensuring compatibility between NASA requirements and FAA regulations. Furthermore, the FAA participates in the Commercial Crew Program milestone reviews.

Q2. Launch abort systems are one of the most critical and technically challenging features to design, integrate and test. What type of launch abort system do you intend to build into your crew system, and how mature is the design? Do you intend to demonstrate it in a relevant launch environment?

A2. SpaceX concurs that launch abort systems (LAS) are critical and technically challenging, which is why our LAS development is the centerpiece of our commercial crew effort. SpaceX's crew Dragon will include an integrated launch abort system (LAS), which will yield numerous safety and performance benefits. The Dragon's LAS is carried through orbit and reentry, with the abort systems available for use throughout the time the Dragon is boosted into space. Carrying the abort system all the way into orbit eliminates the jettison-effectively a stage separation event-of the abort system as a required event for the safe completion of a nominal mission. Separation events are, historically, a leading factor of launch failures.

The Dragon LAS is a vehicle-integrated, side-mounted engine system selected for its safety, reliability and performance. Eight abort engines, or SuperDracos, are located around the periphery of the Dragon service section and are fed by hypergolic propellant stored in the spacecraft propellant tanks. In the event of a mishap or launch failure, the SuperDracos will push the Dragon spacecraft and crew away from the booster. This abort capability is maintained from the pad all the way through nominal on-orbit separation of Dragon from the second stage.

To date, SpaceX has successfully completed five of the ten milestones in our CCDev2 Space Act Agreement (SAA). The completion of these milestones represents $40M of NASA's $75M funding under SpaceX's CCDev2 agreement. During the execution of these milestones, SpaceX provided NASA with comprehensive Falcon 9/Dragon crew systems concept design insight, including cabin layout, seat design, space suit design, and life support system design. Further, SpaceX provided detail for abort scenarios, concepts for the launch abort system, ground systems, abort trajectories, and aerodynamics of ascent and entry and mass margins. The Design Status Review provided an opportunity for SpaceX to work with NASA and industry teammates as partners and make desired crew systems design concept changes subsequent to peer review. This feedback on the system-level designs and concepts constituted a successful collaboration between NASA and SpaceX under the SAA contracting structure.

With regard to the LAS components PDR-our fourth milestone-SpaceX engineers demonstrated to NASA's satisfaction that the LAS propulsion components design is

mature enough to support proceeding with detailed design, fabrication, assembly, integration and testing of LAS propulsion components test articles. SpaceX also provided sufficient evidence to demonstrate that the Dragon LAS propulsion design meets all system requirements within acceptable risk and can be developed within schedule.

Future milestones will include abort engine fabrication and testing, as well as further maturation of the vehicle system design and concept of operations. To achieve these milestones, SpaceX has already begun design and construction of a test facility for the launch abort engine at our Rocket Development Facility in McGregor, Texas. The remaining hardware milestones will culminate in all key launch abort system propulsion components undergoing initial fluid and environmental development testing. Here, the SuperDracos will be hot-fire tested for a full duration. SpaceX will further demonstrate throttle capability, which is necessary for abort maneuvers.

Question Submitted by Ranking Member Eddie Bernice Johnson:

Q1. NASA's plan requires the development and certification of the commercial crew systems to occur within a tight timeline, requires the commercial systems to be capable of safe and reliable flight operations by 2016, makes use of new and unproven government-industry development and safety approaches, and has development and operations costs that are still unknown: In that regard, please provide the following questions:

- *What is the evidence that you believe provides the justification for Congress to invest in this commercial crew initiative, and*
- *What your company realistically would require from the U.S. Government to make this initiative a success.*

A1. The NASA Commercial Cargo and Crew Program is a public-private partnership with the U.S. commercial space sector that leverages financial and technical resources to develop, demonstrate, and provide safe, reliable, and low-cost space transportation capabilities to the International Space Station (ISS). At SpaceX, government investment is leveraged with two additional nongovernment sources of capital: private investment and revenue from other markets. In other words, NASA's investment in commercial space transportation capabilities is augmented both by private investment and by advance sales revenue in the commercial and international launch market, such as telecommunication satellite launches and others.

Since the retirement of the Space Shuttle earlier this year, the U.S. has no option but to send hundreds of millions of dollars to Russia annually to purchase seats on Soyuz spacecraft. While the Russians have been a reliable partner in space, they have continually increased their prices, from $48 million per seat in 2007 to $63 million in 2011—an increase of 31 percent in just five years. With the purchase of six seats annually, this equates to a transfer of wealth of over $336 million per year to the Russian government, with an increase to $378 million annually in 2014. This cost escalation demonstrates clearly the need to expeditiously develop new American human spaceflight capabilities to low Earth orbit. The U.S. is outsourcing its space missions and jobs to Russia by relying on Russian Soyuz vehicles to reach the ISS.

The U.S. has always been a human spaceflight leader. However, no new launch vehicle has been developed since the Space Shuttle, an engineering and technical marvel, primarily due to inefficient contracting structures that led to extreme cost and schedule overruns, leading to program termination. This has been a familiar history in recent years. The innovative approach that forms that basis of NASA's Commercial Crew Program, in which private contractors have "skin in the game," and are required to meet performance milestones to receive payment, has already contributed to the successful development of the Falcon 9 launch vehicle and a cargo version of the Dragon capsule.

A robust U.S. Commercial Crew program-built on a firm fixed price, milestone-based, pay-for-performance approach-will leverage private investment to create thousands of American jobs in Florida, Nevada, Colorado, Virginia, Texas, California, Washington, and Alabama depending on the companies that remain involved going forward. According to an April 2010 Tauri Group study, fully funding and implementing the Commercial Crew and Cargo Program would result in an average of 11,800 direct jobs per year over the next five years nationwide. Further, Commercial Crew provides the only affordable way to regain America's human spaceflight capability within the next several years. If Congress is committed to the restoration of this capability for America, it should ensure robust and consistent funding for the program.

Commercial crew and cargo providers actively seek as many new markets as possible for their services, increasing the volume of flights and thus reducing the cost of access to space for all, including NASA. SpaceX already has a substantial non-government customer base, with over 60 percent of our launch manifest consisting of commercial launches. This market diversity allows us to disperse our costs widely and keep them low for U.S. government customers. More broadly, markets for commercial spaceflight include scientific research flights, national security missions, commercial launches for satellites, private space travel, and others. A strengthened U.S. commercial spaceflight industry would bring space launches back to the United States-an outcome SpaceX has already contributed to-from foreign governments to whom the U.S. has recently surrendered that market.

Subsequent to the Committee's hearing in October, NASA has announced that it will initiate another competition for Space Act Agreements for the next round of Commercial Crew development. The details on the next round and the guidelines for proposals have not been released, but SpaceX is planning to participate and submit a proposal. Once we have additional details about the next commercial crew development phase, we will be better able to estimate the necessary federal investment.

Q2. What is your understanding of how third-party liability and indemnification will be addressed for both launch and reentry and for on-orbit operations of any commercial crew transportation system used for NASA ISS servicing?

- *How important an issue is liability and indemnification to any decision your company might make to enter into a Phase 1 or Phase 2 development contract with NASA for a commercial crew system, or to enter into a service contract with NASA to transport astronauts to the ISS?*
- *Do you plan to purchase insurance for your systems as part of your business plan, and how confident are you that adequate insurance coverage will be available privately? If it isn't, what do you plan to do?*

A2. While NASA has not released its final plans for acquiring crew services to the ISS, NASA contracts have traditionally contemplated third-party liability and indemnification. The cross-waiver, indemnification, and insurance requirements in NASA contracts are set forth in 14 CFR 1266, NASA FAR Supplement Part 1828, and FAR Part 28. We anticipate that any commercial crew transportation system that is conducted under a NASA contract will accord with the legal and regulatory requirements guiding third-party liability and indemnification. Should that system require an FAA license, then contractors will be required to obtain that license pursuant to the Commercial Space Launch Act, 51 U.S.C. Ch. 509, §§ 50901–23 (2011).

Liability and indemnification are one of many important factors that impact SpaceX's decision to enter into contracts with NASA. Prior to entering into a development or services contract to transport astronauts to the ISS, it is essential that the applicable liability and indemnification regime be clearly defined. It would be very difficult to appropriately price the services without clearly delineated responsibilities, including any costs associated with the relevant insurance requirements.

SpaceX will purchase appropriate levels of insurance consistent with prudent business practices and all relevant legal, regulatory and contractual requirements. We have no reason to believe that adequate insurance will not be available on the private market as insurance products meeting current FAA/NASA requirements are readily available. In the unlikely event insurance is not available on the private market, a contractor could self-insure or seek indemnification by NASA under the Space Act (Pub. L. No. 85–568).

Q3. During the hearing, you testified that your company could provide commercial crew transportation services within the 2015–2016 timeframe. Please provide the assumptions behind that date, including:

- *the magnitude and timing of funding from NASA,*
- *the timeline assumed for development, integration, testing, and certification, and*
- *the number of certification flights you are assuming will be required.*

A3. In the coming years, SpaceX will collect significant data and experience on the Falcon 9 and Dragon system from upcoming COTS and CRS missions. According to the current schedule , the Dragon spacecraft and Falcon 9 launch vehicle will have flown together at least 8 more times before a crew demonstration if it were to occur by 2015. The Falcon 9 itself is scheduled to launch a total of 14 missions prior to the first Dragon crew mission. The commonality between the cargo and crew

versions of Dragon will generate significant end-to-end flight heritage and operational experience for our system well in advance of any crew flight.

Ultimately, the Falcon 9 will be one hundred percent common as between the cargo and crew vehicles. Therefore, though there is much work ahead, SpaceX already is beyond a Critical Design Review (CDR) equivalent level of maturity—and even into the production phase—with respect to many aspects of the vehicle system. This includes the main propulsion systems, structures, thermal protection systems (including the Dragon heat shield), power generation systems, altitude control, on-orbit propulsion systems, thermal control systems, and GNC systems.

SpaceX has been steadily progressing through our CCDev2 milestones, which are focused on accelerating development of our launch abort system. As you know, NASA recently elected to pursue Space Act Agreements (SAA) for the next phase of the Commercial Crew Development program. NASA determined that an SAA approach will "offer more flexibility and efficiency in adjusting to future appropriations" and enhance "partner flexibility in technical development through the next phase."[1] SpaceX looks forward to receiving more details on NASA's plans for this phase, will be better able to predict our future schedule for development, integration, testing and, depending on NASA's certification process, provide transportation services within the 2015 timeframe. SpaceX defers to NASA with regard to the number of certification flights that will be required and makes no assumptions in that regard.

Q4. Would you anticipate any additional capacity on the Dragon capsule after taking into account NASA's crew requirements on ISS crew rotations?

- *How will that overcapacity be dealt with?*
- *Will NASA be required to procure the entire spacecraft, or will they be able to just purchase the required number of seats for each flight?*
- *If passengers not paid for by NASA are transported on the flight, how will their stay on the ISS be accommodated and for how long?*
- *Are you assuming the ISS partnership will host the non-NASA spaceflight participants on the ISS?*
- *If you are planning to fly extra passengers on each flight, how do you plan to get them back from ISS in an emergency if the Dragon capsule is also supposed to serve as an ISS crew rescue vehicle?*

A4. The goal of SpaceX's crew transportation system is to safely and reliably transport up to seven crew members from our launch pad on Cape Canaveral to the International Space Station (ISS), dwell on the ISS for up to 210 days and return the same number of crew safely to Earth. As America's national laboratory in space, the ISS productivity depends on how many scientists can visit the lab, conduct their experiments and return to their public or private enterprises. NASA currently bases astronauts at the ISS for six months. That limitation is based on how many Soyuz capsules are produced each year, how long the Soyuz is rated to last on orbit and the high price of Soyuz seats.

The ISS can actually support seven crew members once we have a better crew rescue capability. Commercial crew will deliver that capability. Should the U.S. space industry lower the cost to between $20 and $30 million per seat, it will be possible for research scientists to visit the ISS for shorter periods of time, conduct dedicated research and return to Earth. Less costly, more regular access to ISS will enable more scientists to do more research in the same amount of time, with the same amount of dollars.

Since NASA has not released its final plans for acquiring crew services to the ISS, it is too soon to anticipate if the Dragon will have additional capacity beyond NASA's crew. SpaceX anticipates that NASA will purchase seats on the Dragon in a similar fashion as NASA procures seats on the Russian Soyuz. SpaceX's commercial crew proposals to date have been premised on developing a safe and affordable crew capability that NASA will be able to procure as a commercial service rather than bearing the burden of acquiring the entire spacecraft.

The Commercial Crew Program is still in the development stage. Should NASA select SpaceX for future crew development efforts and eventually for a crew services contract, SpaceX will work with NASA to resolve questions about excess capacity, non-NASA participants, ISS visits and ISS emergency evacuations.

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[1] NASA Commercial Crew Program, Commercial Crew Program Near Term Strategy Discussion. December 2011.

Q5. NASA is providing your company with an additional 42% of the original funding provided for developing a commercial cargo transportation system to buy down risk and assure that commercial cargo resupply services to the ISS are ready when NASA needs them. How can Congress have confidence that a commercial crew program, which is more challenging than developing systems to deliver cargo, will be any different and not require additional funding further down the road?

A5. The Commercial Orbital Transportation Services (COTS) augmentation milestones exceeded the tests and demonstrations originally agreed to by SpaceX and NASA for COTS when the parties first signed their Space Act Agreement. Specifically, certain milestones augmented pre-planned ground and flight testing, others accelerated the development of enhanced cargo capabilities, and the remaining focused on infrastructure improvements. The additional milestones further developed the ground infrastructure needed for cargo carriage operations and helped improve the launch and recovery operations, test site and production facility infrastructure. In short, COTS augmentation milestones were meant to further reduce risk and enhance the execution of the cargo demonstration and operational missions to be performed under the COTS and CRS programs. NASA divided these milestones among multiple amendments due to the uncertainty in Fiscal Year 2011 funding.

Since the hearing in October, NASA has announced that it will alter its approach to the next stage of commercial crew development and is delaying moving forward with the Commercial Crew Integrated Design Contract (CCIDC). Instead, NASA is planning to initiate another competition for Space Act Agreements. NASA specifically cited the Fiscal Year 2012 funding level and ″the uncertainty with the FY13 and FY14 budget levels″ as a key cause for "adjusting the near-term strategy."[2]

Further details on the next round and the guidelines for NASA's commercial crew development Space Act Agreements have not been released. Once those are released, the industry and Congress will have a better sense of the funding required to participate in the next commercial crew development and the timeline for the program.

Q6. NASA has proposed that the first phase of its commercial crew procurement—the Integrated Design Contract—be awarded as a fixed-price contract. From your perspective, is that a manageable approach?

- *How would you plan to balance risk mitigation and flight test programs, which can be expensive, against the need to keep within the contracted-for fixed-price limits?*

A6. NASA has elected to pursue Space Act Agreements (SAA) for the next phase of the Commercial Crew Development (CCDev) program rather than the previously-proposed Commercial Crew Integrated Development Contract (CCIDC). SpaceX strongly supports firm fixed-price contracts, whether SAAs or FAR-based, as providing the best value for the taxpayer. To date, SpaceX has solely operated under firm fixed-price contracts, and believes this approach is manageable, provides contractors with proper incentives, and will help keep costs low as compared with cost-plus contracts. Firm fixed-price (FFP) contracts have proven that they deliver those results. For example, development of the Falcon 9 and cargo Dragon under the Commercial Orbital Transportation Services (COTS) program was undertaken under a FFP.

By contrast, cost-plus contracts have resulted in cost overruns and schedule delays, and ultimately have resulted in no new domestic launch vehicle since the Space Shuttle. Indeed, NASA's internal studies using the NASA-Air Force Cost Model (NAFCOM) concluded that it would have cost NASA $1.7B to $4B to develop the Falcon 9 rocket. By contrast, in partnership with NASA's COTS program, SpaceX developed the Falcon 9 for approximately $300M under its firm fixed-price Space Act Agreement.

Firm fixed-price contracts make the most sense when requirements are properly identified and milestones are effectively negotiated. NASA and SpaceX will incorporate risk mitigation and flight testing into its FFP milestone-based, pay for performance contracts under Space Act Agreements as the CCDev program progresses. The clearest example of this approach is the Falcon 9/Dragon demonstration mission under the COTS program. FFP contracts do not inhibit risk mitigation or rigorous testing. In fact, they allow NASA and the contractor to negotiate those terms and

[2] NASA Commercial Crew Program, Commercial Crew Program Near Term Strategy Discussion. December 2011.

milestones at a high level of specificity on the front end of a contract, prompting payments when milestones are reached.

The Government Accountability Office (GAO) has recently identified NASA's firm fixed-price approach for CCDev as one its "good acquisition practices." Further, GAO states: "We have reported that the use of firm-fixed-price contracts-along with well-defined requirements and a sufficient level of knowledge about critical technologies-presents the least risk to the government. Firm fixed-price contracts place the onus on the contractor to provide the deliverable at the time, place, and price negotiated by the contractor and the government. In addition, firm fixed-price contracts place the maximum risk on the contractor as well as full responsibility for all costs and any resulting profit or loss" (GAO–12–282 NASA Commercial Crew Program).

Question Submitted by Representative Paul Broun

Q1. What obligation does your company have under space act agreements to report anomalies to NASA? What information do you believe your company is obligated to provide NASA about anomalies under a space act agreement? How long after an anomaly is detected, observed, or identified, do you believe your company is obligated to report such an anomaly to NASA under a space act agreement?

A1. The obligations to report anomalies under a Space Act Agreement are well-defined. Under SpaceX's Space Act Agreement (SAA) for the Commercial Orbital Transportation Services (COTS) program, we are required to "[i]dentify any anomalies with preliminary assessment of cause" for each mission. When SpaceX documents an anomaly, we report it to NASA with our preliminary analysis of the anomaly's cause and then we work to NASA on the resolution.

SpaceX's COTS SAA provides NASA with significant insight into SpaceX's operations and includes a number of obligations and reporting requirements that include anomaly reporting assessment and corrective actions. SAA's provide NASA with the ability to require anomaly reporting and information as well as a process for reviewing and resolving any anomalies observed during work taking place under the SAA.

Q2. What obligation does your company have under traditional contracting to report anomalies to NASA? What information do you believe your company is obligated to provide NASA about anomalies under traditional contracting? How long after an anomaly is detected, observed, or identified, do you believe your company is obligated to report such an anomaly to NASA under traditional contracting?

A2. The obligations to report anomalies under a traditional contracting mechanism are determined by the contract. SpaceX's Commercial Resupply Services (CRS) contract to provide NASA with ISS cargo services is a Federal Acquisition Regulation (FAR) contract. The FAR provides a framework for NASA to include mission-specific requirements in its contracts, including anomaly reporting. During its procurement process and negotiations with its contractors, NASA determines the level of insight and oversight it requires.

For example, the following obligations are part of NASA's insight and approval authority under SpaceX's CRS contract:

> *The Contractor shall notify NASA of qualification or test anomalies involving ISS Commercial Resupply launch and orbital vehicles, systems, subassemblies, components, software and similar launch and orbital vehicles that the Contractor is aware of.*
>
> In the event of an in-flight anomaly or launch, on-orbit or entry failure, the Contractor shall allow NASA to participate fully in the Contractor's Failure Investigation Board including those for non-NASA missions.
>
> Our CRS contract provides NASA with significant insight into SpaceX's operations and includes a number of obligations and reporting requirements that include anomaly reporting assessment, corrective actions. Those requirements appear in various parts of the contract.

Q3. What obligation does your company have under the modified FAR acquisition to report anomalies to NASA? What information do you believe your company is obligated to provide NASA about anomalies under a modified FAR acquisition? How long after an anomaly is detected, observed, or identified, do you believe your company is obligated to report such an anomaly to NASA under modified FAR acquisition?

A3. Please see the response above. Any differences in anomaly reporting obligations between a traditional FAR acquisition, a modified FAR acquisition, or a Space Act Agreement would be determined by NASA in the contract.

Question Submitted by Representative Jerry Costello

Q1. NASA's FY 2012 budget request proposes a total of $4.25 billion over five years, or $850 million a year through 2016, to fund the U.S. government's share of commercial crew capabilities development for one or more systems. What do you believe, in terms of a percentage of total development costs the private sector might realistically contribute?

- *What percentage is you company planning to contribute?*
- *Is private sector investment contingent on additional, non-financial U.S. government support too? If so, what would that support involve?*

A1. At SpaceX, government investment is leveraged by at least one additional non-government source of capital, including private investment and revenue from other markets. In other words, NASA's investment in commercial space transportation capabilities is augmented both by private investment and by advance sales revenue in the commercial and international launch market, such as telecommunication satellite launches and others.

Commercial crew and cargo providers actively seek as many new markets as possible for their services, increasing the volume of flights and thus reducing the cost of access to space for all, including NASA. Markets for commercial spaceflight include scientific research flights, national security missions, commercial launches for satellites, private space travel, and others. A strengthened U.S. commercial spaceflight industry would bring space launches back to the United States from foreign governments who have increasingly taken over the market.

Since the hearing in October, NASA has announced that it will alter its approach to the next stage of commercial crew development to initiate another competition for Space Act Agreements. The details on the next round and the guidelines for proposals have not been released, though SpaceX is planning to participate and submit a proposal. Once we have greater details about the next commercial crew development phase, we will be better able to estimate the private sector contribution.

Our continued investment will not be contingent upon that support continuing; however, we believe it provides valuable benefits to NASA and its industry partners. Under NASA's Space Act Agreements for COTS and commercial crew development, industry has received non-financial U.S. government support, generally in the form of technical assistance by NASA experts and centers. SpaceX's participation in COTS and CCDev2 has not been contingent upon non-financial U.S. Government support, though NASA's technical support has contributed to the success of our partnership.

Q2. What is your reaction to NASA's proposed approach to human-rating future commercial crew transportation systems? Do you believe NASA's proposed approach will both ensure astronaut safety and facilitate eventual FAA licensing of launches for non-government customers? Are there any changes you would like to see made to the approach?

A2. NASA has been safely transporting astronauts into space for 50 years. Building on its decades of experience, earlier this month, NASA released the baselined version of the CCT–1100 Series. Those documents will provide valuable guidance to industry on NASA's human rating requirements as we continue development of future commercial crew transportation systems. NASA's oversight coupled with SpaceX's innovative vehicle design—which in many cases exceeds the NASA requirements—will improve safety by a factor of ten compared to previous human-carrying spacecraft. The resulting transportation system is also expected to satisfy the FAA licensing requirements.

Q3. During the hearing, you testified that your company is investing about 60 percent of the cost of your commercial crew activities relative to what the government is investing in your program. Do you intend to maintain that percentage should you receive an award for the design and development contracts from NASA? If not, what level of investment would you anticipate contributing for the design and development contract phase?

A3. Since the hearing in October, NASA has announced that it will alter its approach to the next stage of commercial crew development to initiate another competition for Space Act Agreements. The details on the next round and the guidelines

for proposals have not been released, though SpaceX is planning to participate and submit a proposal. Once we have greater details about the next commercial crew development phase, we will be better able to estimate the private sector contribution. However, SpaceX is committed to substantial investment as part of this program.

Q4. During the hearing, you testified that you would commit in current year dollars to a price of $140 million for commercial crew for a seven astronaut flight and at a flight rate of four crewed flights per year.

a. Do you anticipate any additional capacity on the four flights, after taking into account NASA's requirements for ISS crew rotations? If so, how would you plan to fill the remaining seats on those flights included in the four flights per year rate?

b. Would NASA assume the cost of the entire flight if any seats were not filled?

A4. The goal of SpaceX's crew transportation system is to safely and reliably transport up to seven crew members from our launch pad on Cape Canaveral to the International Space Station (ISS), dwell on the ISS for up to 210 days and return the same number of crew safely to Earth. SpaceX's commercial crew proposals to date have been premised on developing a safe and affordable crew capability that NASA will be able to procure as a commercial service.

Since NASA has not released its final plans for acquiring crew services to the ISS, it is too soon to anticipate if the Dragon will have additional capacity beyond NASA's crew. SpaceX anticipates that NASA will purchase seats on the Dragon in a similar fashion as NASA procures seats on the Russian Soyuz. Should NASA select SpaceX for future crew development efforts and eventually for a crew services contract, SpaceX will work with NASA to resolve questions about excess capacity, non-NASA participants, ISS visits and ISS emergency evacuations.

Q5. Following the hearing, it was reported that SpaceX may not bid on the commercial crew development contract if NASA does not change the terms in the draft version of the contract. Is that correct?

A5. The report was inaccurate and was changed by the reporter. SpaceX plans to submit a proposal to participate in the next phase of NASA's commercial crew development program. The company was founded to develop the safest, most reliable and affordable crew transportation system to low Earth orbit and, ultimately, beyond. Indeed, carrying humans into space has been a cornerstone of SpaceX's vehicle designs from the day the company was founded.

Since the hearing in October, NASA has announced that it will pursue competitively-awarded Space Act Agreements for the next stage of commercial crew development. The details on the next round and the guidelines for proposals have not been released, though SpaceX is planning to participate and submit a proposal.

Responses by Mr. Charlie Precourt, Vice President, ATK Launch Systems Group, Brigham City, UT

Question Submitted by Chairman Ralph Hall

Q1. How confident are you about NASA's and FAA's ability to coordinate their requirements for commercial crew launches? Have you seen any evidence yet that the two agencies are attempting to define roles and responsibilities, and to minimize overlap?

A1. ATK believes that a working relationship is being developed between the two agencies for the ISS Commercial Resupply program which can be evolved to manage a Commercial Crew Transportation program. The FAA also has established a Commercial Space Transportation Advisory Council that includes industry membership to engage in issues surrounding roles and responsibilities for commercial spaceflight operations. The input from the COMSTAC informs the FAA on approaches that can be taken in its interface with NASA and other government agencies relative to commercial space activities.

Question Submitted by Ranking Member Eddie Bernice Johnson

Q1. Please provide the evidence that provides the justification for Congress to invest in this commercial crew initiative and what would your company realistically require from the U.S. Government to make this initiative a success.

A1. The question raises appropriate issues relative to the commercial crew program's readiness to support ISS schedule requirements as well as the expected levels of safety, reliability, and the costs of development and operations in fielding a commercial system. One of the biggest factors that will influence the outcome of all of these questions is the certification process to be used by NASA for the commercial vehicles. The amount of testing and certification documentation required to be awarded a commercial crew delivery contract is not yet known. The certification process ultimately will affect schedule, cost, performance, reliability and safety.

It is hoped the process for certification can become clear during the next phase of the development program, so that industry can better estimate the costs to be carried in its business approach. To make this initiative a success, our company would require a contract for services beyond the development program that is specific in terms of numbers of flights and prices. This was done for commercial cargo services during NASA's COTS program. The Commercial Resupply Services contracts were awarded to the COTS contractors while development was still underway. This enabled the companies to project realistic returns on investment for the program. To date, this has not been addressed by NASA for the commercial crew program. The development activities for commercial crew could take longer than for cargo services, making the need for early services contracts all the more important to ensure reasonable returns on investment are achievable.

Q2. What is your understanding of how third-party liability and indemnification will be addressed for both launch and reentry and for on-orbit operation of any commercial crew transportation system used for NASA ISS servicing?

A2. At this time, ATK understands that NASA will procure commercial launch services, and the services will be provided and licensed under the FAA authority, which dictates the required insurance coverage, as well as the Government indemnification coverage. We also anticipate that a Cross Waiver of Liability for Space Station Activities, similar to Commercial Resupply, will be incorporated into any resulting contract.

Q3. How important an issue is liability and indemnification to any decision your company might make to enter into a Phase 1 or Phase 2 development contract with NASA for commercial crew system, or to enter into a service contract with NASA to transport astronauts to the ISS?

A3. While there are extremely talented people designing rockets and conducting a rigorous certification process, there are potential risks that could financially destroy a company. Without insurance coverage and ultimately indemnification, the risks would be too great to enter into the launch services business.

Q4. Do you plan to purchase insurance for your systems as part of your business plan, and how confident are you that adequate insurance coverage will be available privately? If it isn't, what do you plan to do?

A4. ATK plans to acquire the insurance required by an FAA License and has had discussions with the Insurance industry and believes that insurance will be available.

Question Submitted by Representative Paul Broun

Q1. What obligation does you company have under space act agreements to report anomalies to NASA?

A1. ATK does not have any space act agreements that spell out a requirement for anomaly reporting. However, as a result of ATK's ongoing relationship with NASA on several contracts, ATK provides NASA insight to events and anomalies as soon as they occur, whether required contractually or not. Generally, the aerospace industry openly reports anomalies to ensure that they aren't unnecessarily repeated on other operating systems, or on other programs, due to lack of insight. This is a common lessons learned practice in the industry, and is done in a manner that enables learning while protecting proprietary information.

Q2. What information do you believe your company is obligated to provide NASA about anomalies under a space act agreement?

A2. This is dependent on the type of space act agreement, the scope of the agreement, and the requirements contained in the agreement. For example, if an agreement required hardware performance and anomaly reporting, ATK would be obligated to provide information relative to the anomaly.

Q3. How long after an anomaly is detected, observed, or identified, do you believe you company is obligated to report such an anomaly to NASA under a space act agreement?

A3. This is dependent on the type of a space act agreement, the scope of the agreement, and the requirements contained in the agreement. As noted in the response to question #1, we generally report anomalies as a normal way of doing business.

Q4. What obligation does your company have under traditional contracting to report anomalies to NASA?

A4. ATK is required to report failure and anomalies upon occurrence or detection for any and all anomalies.

Q5. What information do you believe your company is obligated to provide NASA about anomalies under traditional contracting?

A5. ATK is required to provide reporting on ten items

1. A failure
2. An overstress or a result of an overstress of equipment and/or material
3. An unsatisfactory condition
4. An unexplained anomaly
5. An alert applicable to flight hardware
6. Failure of Critical Items List (CIL) hardware that fail in critical failure modes
7. Affects accepted delivered hardware
8. In-flight anomaly
9. Ground Support Equipment (GSE) Nonconformance
10. Contractor/Customer request

Q6. How long after an anomaly is detected, observed, or identified, do you believe you company is obligated to report such an anomaly to NASA under traditional contracting?

A6. Upon occurrence or detection (as soon as feasible).

Q7. What obligation does your company have under the modified FAR contracting to report anomalies to NASA?

Q8. What information do you believe your company is obligated to provide NASA about anomalies under a modified FAR acquisition?

Q9. How long after an anomaly is detected, observed, or identified, do you believe you company is obligated to report such an anomaly to NASA under modified FAR acquisition?

A7–9. As noted in my response to question #1, we feel we are morally obligated to provide anomaly reporting as soon as practical regardless of contractual requirements. In our history, there have been numerous examples where we were assisted

by both the contracting agency and competitors in anomaly resolution and similarly, we assisted competitors and contracting agencies in analyzing and resolving their anomalies. Typically the industry works in this fashion to avoid unnecessary failures on similar systems on other programs. The process is as open as possible while protecting proprietary data. ATK feels that providing the launch services NASA is pursuing, be it payloads or people, is an extremely valuable and critical requirement for the nation. As such, ATK would not alter the approach to anomaly reporting currently in practice for the vast majority of our contracts if a modified FAR acquisition approach is taken.

Question Submitted by Representative Jerry Costello

Q1. What do you believe, in terms of a percentage of total development costs, the private sector might realistically contribute? What percentage is your company planning to contribute? Is private sector investment contingent on additional non-financial U.S. government support too? If so what would that support involve?

A1. The percentage contribution from the private sector is directly proportionate to the return on investment that can be expected from the future sales of the product (in this case a launch service). Currently, for commercial crew services, there are many assumptions being made to create future business models. As a point of reference, one can look to the production of commercial aircraft for the airline industry, where 100% of the upfront investment is borne by industry. This is achievable because of the high numbers of aircraft ordered resulting in a positive return on investment.

In the case of commercial crew services however, the number of flights (demand levels for the service) is likely to be six per year or less. The flight rate expectation will set the price levels required to generate a positive return on investment. If industry invested 100% in system development while anticipating these flight rates, the cost per flight required to recoup the investment would be extremely high. Therefore, government must offset the upfront costs so that investments from industry can be reasonably amortized. Using assumptions based on our best understanding of the NASA plan during the CCDev2 timeframe, ATK required 50% or less of the up-front investment from the government. However as changes in the NASA plan occur, the amount that ultimately is our contribution would change accordingly. For example, should NASA test and certification requirements prove to be more costly than we have assumed, then the investment percentages would be affected.

Similarly, if NASA's acquisition strategy changes, or the number of flight services ordered is lower than currently anticipated, then the cost per flight or the upfront government investment, or both would be affected. Given these uncertainties in the ultimate flight rates or contractual requirements through demonstration, test and initial operational capability, it is essentially impossible to define a set percentage investment that would be reasonable for industry to make. In the absence of this clarity, we make reasonable assumptions as a starting point for our investment with the expectation there will be changes as NASA's final requirements, and the means to pay for them, become better understood. Finally, private sector investment also depends on other additional, non-financial U.S. government support. This is most notable in the area of launch site infrastructure and other government facility and equipment access. Costs to industry for access to the government owned assets will ultimately affect the viability of the commercial approach. There are various means to address these costs, but will be the government's responsibility to determine.

Q2. What is your reaction to NASA's proposed approach to human-rating future commercial crew transportation systems? Do you believe NASA's proposed approach will both ensure astronaut safety and facilitate eventual FAA licensing of launches for non-government customers? Are there any changes you would like to see made to the approach?

A2. The most important consideration for human-rating is to ensure that standards we know to be technically achievable, and that would result in increases in astronaut safety relative to Shuttle, are not compromised for budget or other financial reasons. Although NASA has released its human rating requirements, it is not yet clear what will be required to be certified to those requirements. The means to prove a system meets the human rating requirement are still to be defined in a certification process. The cost for this process therefore is also an unknown. As those costs become better understood, there may be pressure to do less than what is achievable in the way of safety and reliability for the astronauts in a crew transpor-

tation system. NASA should maintain the highest achievable standards for both their human rating requirements and their certification process to ensure we deliver the safest, most reliable system possible.

Q3. During the hearing, you testified your company plans to have 50% of the cost come from outside, non-government investment. Do you intend to maintain that percentage should you receive an award for the design and development contracts from NASA? If not what level of investment would you anticipate contributing for the design and development contract phase?

A3. Please see the answer to Question 1 above. Additionally, we would intend to maintain a level of investment that minimizes government costs and would strive to maintain our original business model and carry the original assumptions. However, as mentioned in the answer to question 1 above, the NASA acquisition strategy, schedule and ultimate requirements continue to evolve, all of which affect the business model and the required costs to be amortized over the life of the system. As a result, the exact percentages of our investment relative to the total system development cost are likely to change in an iterative fashion as the NASA plans become clearer.

Responses by Dr. George Sowers, Vice President,
United Launch Alliance, Englewood, CO

Question Submitted by Chairman Ralph Hall

Q1. How confident are you about NASA's and FAA's ability to coordinate their requirements for commercial crew launches? Have you seen any evidence yet that the two agencies are attempting to define roles and responsibilities, and to minimize overlap?

A1. ULA strongly supports both Congress' and NASA's efforts to develop a commercial capability to meet U.S. obligations to deliver crew to and from the International Space Station. ULA has been extremely encouraged at the level of cooperation between NASA and the FAA in working jointly to develop and coordinate requirements and certification processes for commercial crew launches. Both agencies are bringing their expertise and unique experience to work cooperatively towards the goal of developing a safe and affordable domestic capability to transport crew to low earth orbit. NASA has decades of human spaceflight experience which directly complements the FAA's decades of experience certifying commercial and civilian aircraft, and licensing of commercial space launches. ULA is confident that both agencies will work cooperatively to define mutually beneficial roles and responsibilities, while proactively seeking input from the commercial crew service providers.

Question Submitted by Ranking Member Eddie Bernice Johnson

Q1. NASA's plan requires that development and certification of the commercial crew systems to occur within a tight timeline, requires the commercial systems to be capable of safe and reliable flight operations by 2016, makes use of new and unproven government-industry development and safety approaches, and has development and operations costs that are still unknown. In that regard, please provide the following questions:

a. What is the evidence that you believe provides that justification for congress to invest in this commercial crew initiative, and

A1 a. The primary justification to invest in the commercial crew initiative is that the nation needs this strategic capability to maintain our nation's leadership in human spaceflight and is required to meet U.S. obligations to the ISS partners. We should have an urgency to get a commercial service up and operating as quickly as possible to close the U.S. Human Spaceflight "Gap" and to continue to exploit the investment that we've made in the ISS.

The Government of Russia is NASA's sixth largest contractor, receiving over $350M per year. Not only does this represent thousands of high tech jobs sent overseas, but it's ceding our leadership as a space-faring nation. Furthermore, the Russian Soyuz vehicle now represents the only means to send crew to the station. The recent failure of that normally reliable craft reminds us that the very existence of the ISS is now in jeopardy, and that we are reliant on a single fragile lifeline that we have little insight into or control over.

Finally, the establishment of a commercial crew initiative has the potential to stimulate an entire new economic sector with thousands of high tech jobs. For example, Bob Bigelow is a visionary with a dream of a fleet of private space stations. His customer base will be countries that want a space program but afford time on the ISS. But Bob needs a safe and affordable transportation system to orbit. NASA is in a unique position to create a transportation system that can address the nation's needs for access to ISS, while also providing an opportunity to unleash the power of the U.S. entrepreneur in Low Earth Orbit.

b. What your company realistically would require from the U.S. Government to make this initiative a success

A1 b. The private sector has the expertise to provide crew transportation safely and can provide the best value to the taxpayer. The companies competing for the commercial crew service include those with decades of experience in NASA's human spaceflight program, such as Boeing. Newer companies bring fresh ideas and the entrepreneurial spirit like Sierra Nevada, Blue Origin and SpaceX. The private sector already possesses the world's most reliable rocket with the Atlas V.

In order to make the commercial crew initiative a success, U.S. Industry needs the Congress to commit to provide adequate development funding. With adequate

funding, Atlas could be ready to support test flights in 2014 and operational flights in 2015.

Q2. What is your understanding of how third-party liability and indemnification will be addressed for both launch and reentry and for on-orbit operations of any commercial crew transportation system used for ISS servicing?

a. How important an issue is liability and indemnification to any decision your company might make to enter into a Phase 1 or Phase 2 development contract with NASA for a commercial crew system, or to enter into a service contract with NASA to transport astronauts to the ISS?

A1 a. Liability and indemnification are very important considerations to ULA. With the addition of crew members, gaps in coverage exist currently for ISS on-orbit activities under existing indemnification regimes like the Commercial Space Launch Act, and the unavailability of insurance for certain potential claims, it is important that our company be protected against new and significant risks associated with these missions. Gaps in statutory liability coverage and lack of insurance for on-orbit activities have the potential to expose companies to significant risk in the event of damage to the ISS or injury to its occupants and crew members during on-orbit activities.

b. Do you plan to purchase insurance for your systems as part of your business plan, and how confident are you that adequate insurance coverage will be available privately? If it isn't, what do you plan to do?

A1 b. ULA intends to purchase insurance for third party liability claims associated with the ascent phase of the mission—up to separation of the crew capsule from the launch vehicle second stage. This is consistent with our existing CSLA and NASA Act obligations. However, this coverage only protects against third party liability claims for bodily injury and property damage. In addition, we intend to seek waivers from crew members or rely on statutory and/or prime contract protections to protect us against claims from crew members in the event of a launch accident. Insurance may also be an option to protect against crew member claims, although cost and availability has not been fully determined. Although we have no performance obligations beyond the ascent phase, we intend to request coverage from the prime contractor for any potential crew member or third party claims beyond this phase. To our knowledge, insurance coverage for on-orbit activities is unavailable and we have not examined coverage for crew re-entry activities because we will not be performing that phase of the mission.

Q3. In you prepared statement, you note that the Atlas 5 is the only launch vehicle certified by NASA to carry Category 3 missions, "a category reserved for NASA's most important science missions". What did it take for ULA to achieve Category 3 certification and how does that compare to the requirements for commercial crew certification as you understand them?

A3. NASA Policy requires that launch vehicles are selected based on the complexity and risk of the payload. As such, NASA has identified a rigorous certification process that includes such things as a NASA Flight Margin Verification (FMV) which is verification by NASA that the launch vehicle meets the predicted vehicle and performance parameters. In addition, all flight anomalies and mission failures are required to be resolved. NASA also requires a comprehensive IV&V assessment of all analyses, involving independent modeling, model evaluation, and/or analytical review.

In order to ensure the highest levels of safety, ULA envisions an equivalent assessment that builds upon the Category 3 Certification, with particular emphasis on launch vehicle designs and operations that my pose a safety hazard to the flight crew.

Question Submitted by Representative Paul Broun

Q1. What Obligation does your company have under space act agreements to report anomalies to NASA?

Q2. What information do you believe your company is obligated to provide NASA about anomalies under a space act agreement?

Q3. How long after an anomaly is detected, observed, or identified, do you believe your company is obligated to report such an anomaly to NASA under a space act agreement?

Q4. What Obligation does your company have under traditional contracting to report anomalies to NASA?

Q5. What information do you believe your company is obligated to provide NASA about anomalies under traditional contracting?

Q6. How long after an anomaly is detected, observed, or identified, do you believe your company is obligated to report such an anomaly to NASA under traditional contracting?

Q7. What Obligation does your company have under the modified FAR acquisition to report anomalies to NASA?

Q8. What information do you believe your company is obligated to provide NASA about anomalies under a modified FAR acquisition?

Q9. How long after an anomaly is detected, observed, or identified, do you believe your company is obligated to report such an anomaly to NASA under modified FAR acquisition?

A1–9. Regardless of the contacting method, ULA standard policies require prompt identification, government customer notification, and initiation of an investigation are key tenets of successfully resolving and learning from anomalies. ULA has instituted processes to ensure that when an anomaly occurs, a proper investigation is performed, proper leadership is involved, independent oversight is included, and ULA and customer management team members are regularly briefed on the status of the investigation. For example, within hours following the occurrence of a major anomaly, ULA notifies Customer/government representative(s) and major subcontractor/partner representative(s).

In addition to these formal notifications, government awareness is often instantaneous since NASA or Air Force representatives typically participate in launches and major tests. ULA accommodates this participation even if the operation is not specifically for that government customer. Depending on the level of anomaly, customers and government representatives are invited to participate in the Anomaly Investigation Teams and Oversight Boards. All of this is consistent with ULA's practice of providing open and detailed technical insight to the U.S. Government.

Question Submitted by Representative Jerry Costello

Q1. NASA's FY 2012 budget request proposes a total of $4.25billion over five years, or $850 million a year through 2016, to fund the U.S. government's share of commercial crew capabilities development for one or more systems. What do you believe, in terms of a percentage of total development costs, the private sector might realistically contribute?

A1. ULA is providing the flight-proven Atlas V launch vehicle as one element of the overall commercial crew capability. Atlas V was developed by the Lockheed Martin Corporation as part of the Evolved Expendable Launch Vehicle (EELV) Program. Lockheed Martin invested nearly $2.0B in the development of the Atlas V.

ULA will not be providing the entire crew transportation services from launch through landing, and as such, is not in a position to comment on the total development costs for the services. ULA has identified the relatively few enhancements required to Atlas V for the commercial crew initiative. These enhancements will be funded via a combination of contracted activities and company funded development.

a. What percentage is your company planning to contribute?

A1 a. ULA embraces a philosophy of "Continuous Improvement" whereby we fund initiatives that improve our efficiency and reduce our costs. We are currently investing approximately $40M per year in initiatives that will directly benefit all our customers, including the commercial crew initiative.

b. Is private sector investment contingent on additional, non-financial U.S. government support too? If so, what would that support involve?

A1 b. ULA does not have a need for additional, non-financial U.S. government support for the commercial crew initiative.

Q2. What is your reaction to NASA's proposed approach to human-rating future commercial crew transportation systems? Do you believe NASA's proposed approach will both ensure astronaut safety and facilitate eventual FAA licensing of launches for non-government customers? Are there any changes you would like to see made to the approach?

A2. If NASA's commercial crew program is to be successful, every effort must be undertaken to ensure the highest possible level of safety and reliability. A key element of this is the rigorous process of human system certification. Under a Space Act Agreement with NASA, we are conducting a comprehensive assessment of the

Atlas design against NASA's stringent human certification requirements. This entails a part-by-part, system-by-system review of the design, analysis and test pedigree of the Atlas. We are also performing a detailed analysis of the hazards faced by the crew and their mitigation as well as a Probabilistic Risk Assessment for the launch of crew. Our expectation is that the Atlas will fare very well. This is because of the rigor and attention to detail we applied during the original design and development process as well as the flight demonstrated performance of the system through 28 successful missions.

The importance of insight and rigorous human certification criteria has been highlighted by the recent Soyuz failure. For new, unproven vehicles, you need the rigor even more, in addition to establishing a track record of demonstrated and repeatable success.

We have been impressed with the thoroughness and rigor that NASA has used to determine how Atlas met their requirements. Based on this experience, it is our belief that NASA will not compromise astronaut safety solely to develop a commercial crew capability.

Responses by The Hon. Paul Martin, Inspector General, National Aeronautics and Space Administration

Question Submitted by Ranking Member Eddie Bernice Johnson

Q1 a. Your report, NASA's Challenges Certifying and Acquiring Commercial Crew Transportation Services, states that some of NASA's potential commercial crew partners are building spacecraft for the first time, and design and development are under way without fully defined and finalized requirements. What are the risks of developing systems without a set of finalized requirements?

A1 a. Having finalized requirements enhances vehicle reliability, improves mission success, maximizes crew safety, and reduces risks. In addition, final requirements clearly communicate to NASA's commercial partners the design, development, testing, and operations parameters they must meet to achieve certification of their systems. To mitigate the risks of commercial crew partners building spacecraft for the first time without fully defined and finalized requirements, NASA refined the requirements identified in the December 2010 "Commercial Crew Transportation System Certification Requirements for NASA Low Earth Orbit Missions" (Certification Requirements) and on December 8, 2011, NASA released baseline versions of its commercial crew requirements relating to missions to the International Space Station (ISS). Known as the "1100-series," these documents provide additional information to commercial partners regarding roles and responsibilities, technical management processes supporting certification, crew transportation system and ISS services requirements, and the application of technical and operations standards. The release of these documents should help communicate NASA's requirements, standards, and processes for commercial transportation system certification.

Q1 b. Do you agree that NASA has adequately mitigated such risks?

A1 b. It remains to be seen whether NASA has adequately mitigated these risks. However, NASA has taken steps to date to ensure that commercial partners understand the Agency's health and medical, engineering, and safety and mission assurance requirements. As previously stated, in addition to issuing its December 2010 Certification Requirements NASA recently released baseline versions of its 1100-series documents relating to missions to the ISS.

In addition, as we discussed in our June 2011 report, the use of funded Space Act Agreements limits Government control compared to traditional procurement contracts based on the Federal Acquisition Regulations (FAR).[1] Specifically, under such agreements NASA cannot dictate specific system concepts or elements or mandate compliance with its requirements. Accordingly, continuing to use Space Act Agreements in the later stages of the acquisition process could pose risks that the systems developed by commercial partners may ultimately not meet NASA's human-rating requirements and that costly and time-consuming redesigns will be required. To mitigate this risk, at the time we issued our report NASA appeared to be moving away from funded Space Act Agreements toward FAR-based contracts (which allow for more direct Government involvement). However, in mid-December 2011 NASA announced plans to shift back to funded Space Act Agreements due to concerns about overall program funding levels.

Q2. Your report goes on to say "In this type of environment, there is a risk that during the period of contract performance NASA's requirements may change so significantly that contractors can successfully argue that the Agency is changing the contract's scope, in which case NASA could be required to pay the contractor to make necessary modifications." Do you feel that there is a likelihood NASA's requirements will change during the contract? Is this a common trait in development efforts? Has NASA adequately accounted for this cost risk?

A2. Changes in requirements are not uncommon in large scale development efforts. NASA's requirements for crew transportation to the ISS may change based on the needs of the ISS Program and the Agency's future exploration goals. However, NASA has taken steps to minimize this possibility. For example, the Agency has reduced its list of requirements to those it believes are essential to ensure safe and reliable systems. In addition, when possible NASA will allow contractors to propose alternative methods for meeting Agency requirements. Finally, NASA's approach of dividing its acquisition process into phases that separate system design from devel-

[1] "NASA's Challenges Certifying and Acquiring Commercial Crew Transportation Services," NASA Office of Inspector General (June 20, 2011) accessible at http://oig.nasa.gov/audits/reports/FY11/IG–11–022.pdf.

opment, test, evaluation, and certification should help limit the Agency's financial risk.

Question Submitted by Representative Paul Broun

Q1–3. What obligations do companies have to report anomalies to NASA under Space Act Agreements? What information do you believe companies are obligated to provide NASA under a Space Act Agreement? How long after an anomaly is detected, observed, or identified, do you believe a company is obligated to report such an anomaly to NASA under a Space Act Agreement?

A1–3. NASA establishes its expectations with regard to reporting by partner companies in each Space Act Agreement. For example, NASA's funded Commercial Crew Development 2 (CCDev2) Space Act Agreement with Sierra Nevada Corporation requires the company to hold quarterly project status briefings with NASA personnel describing the progress made using a mutually agreed upon quantifiable performance method, any difficulties encountered and corrective action necessary, and the company's plans to move forward. Similarly, the unfunded CCDev2 Space Act Agreement with Excalibur Almaz, Inc. requires the company to hold project status briefings with NASA at each milestone review. To the extent that an anomaly would impact the company's ability to achieve progress or complete an agreed-upon milestone, the Office of Inspector General would expect the company to report such an event to NASA.

Moreover, with respect to funded agreements, partner companies will not receive payment until they demonstrate successful completion of each specified milestone. Further, NASA may terminate agreements for failure to demonstrate progress and timely achievement of milestones. For example, in October 2007 NASA terminated its funded Space Act Agreement with Rocketplane Kistler due to the company's failure to meet agreed-upon milestones.

Q4–6. What obligation does a company have under traditional contracting to report anomalies to NASA? What information do you believe a company is obligated to provide NASA under traditional contracting? How long after an anomaly is detected, observed, or identified, do you believe a company is obligated to report such an anomaly to NASA under traditional contracting?

A4–6. Reporting requirements vary by contract based on factors such as the types of supplies or services purchased, the type of contract vehicle selected, and the dollar value of the acquisition. Specific reporting requirements for technical, cost, and schedule anomalies are reflected in the final negotiated contract. Generally, NASA's FAR-based contracts require the contractor to perform monthly program status reviews to communicate the status of the technical effort, program schedule, and resource conditions, and provide a summary of all open anomalies, problem reports, and program technical issues that may impact the contracted work. Contractors are also required to submit monthly financial management reports that describe actual and planned costs and labor hours, short-term cost projections, estimates to complete, and contract values. Finally, pursuant to NASA regulation, contractors may be required to notify the Government of any mishaps within 1 hour of occurrence.

Q7–9. What obligation does a company have under the modified FAR acquisition to report anomalies to NASA? What information do you believe a company is obligated to provide NASA under a modified FAR acquisition? How long after an anomaly is detected, observed, or identified, do you believe a company is obligated to report such an anomaly to NASA under a modified FAR acquisition?

A7–9. We anticipate any "modified FAR acquisition" undertaken as part of NASA's Commercial Crew Program will be negotiated similar to a traditional FAR-based contract described above.

Q10. Please explain, in detail, the role of NASA's Safety and Mission Assurance Office in the design, development, construction, testing and acquisition of hardware associated with commercial crew services.

A10. NASA's Office of Safety and Mission Assurance (OSMA) has been involved in the development of the Commercial Crew Program from its inception. Many of the requirements that the commercial partners must adhere to are derived from OSMA policies and standards. In addition, according to NASA's plans at the time of our audit, OSMA personnel will participate as members of the NASA Performance Integration Teams that will be embedded at contractor locations during the acquisition phases of the program. These teams will gain insight into the contractor's progress

through observation, document reviews, tests, and compliance evaluations, and will work side-by-side with contractor personnel to provide expertise and aid in the resolution of technical issues. The insight gained will be used to determine whether the contractor has successfully completed agreed-upon milestones.

Question Submitted by Representative Jerry Costello

Q1. In describing fixed-price contracts, your report, NASA's Challenges Certifying and Acquiring Commercial Crew Transportation Services, makes the following caution: "[A]lthough fixed-price contracts provide the maximum incentive for contractors to perform effectively while controlling costs, they also place on the contractor the maximum risk of loss if it is unable to so. This situation can create incentives for a contractor to "cut corners" to protect its profit margin." How can NASA guard against creating such incentives?

A1. As previously discussed, NASA planned to embed at contractor locations Performance Integration Teams and chair or co-chair program control and technical review boards to review the verification of requirements and recommend disposition when a requirement cannot be met by the contractor. The insight and collaboration provided by the Performance Integration Teams, along with the oversight provided by the boards, is designed to identify developmental challenges and prevent the contractor from cutting corners.

Q2. Given the possibility of NASA having only one provider, what would be NASA's recourse if the provider cannot deliver at the agreed-to fixed price, other than paying for the cost increase?

A2. A determination would first have to be made regarding whether the cost increase is due to a requirement change that is outside the scope of the original contract. The contractor is responsible for absorbing cost increases caused by changes that are within the original scope of the contract. However, if the contractor becomes insolvent or refuses to proceed, NASA's only recourse may be to purchase more seats aboard Russia's Soyuz vehicle. As stated in our report, because of the long lead-time required for procuring Soyuz seats and planning a mission to the ISS, NASA would have to make the decision to purchase additional Soyuz seats for flights in 2016 and beyond by spring 2013—at least three years before commercial partners are expected to be ready to provide transportation services.

Additionally, Congress would have to grant another waiver from the restrictions on paying Russia for ISS-related activities contained in the Iran-North Korea-Syria Nonproliferation Act because the current waiver expires in 2016.

Q3. Do you have any examples at NASA or in the Federal government where firm fixed price was used for development programs, both successfully and unsuccessfully?

A3. NASA has most frequently used cost-plus-award-fee contracts for its development programs. Moreover, for approximately 18 years federal agencies were prohibited from using fixed-price contracts for development efforts except in limited circumstances.[2] Consequently, we are not aware of any recent examples of successful development programs using fixed price contracts.

[2] Section 818 of the 2007 Defense Authorization Act repeals Section 807 of the National Defense Authorization Act for fiscal year 1989, which prohibited the use of firm fixed-price contracts except in limited circumstances.

Responses by Mr. William H. Gerstenmaier, Associate Administrator, Human Exploration and Operations Mission Directorate, National Aeronautics and Space Administration

Question Submitted by Chairman Ralph Hall

Q1. Are any changes in launch indemnification being contemplated, especially for flights carrying NASA astronauts?

A1. On December 15, 2011, NASA announced that it will continue to use competitively awarded, funded Space Act Agreements (SAAs) rather than transitioning to contracts for the next phase of the Commercial Crew Program (CCP). Commercial launch and reentry activities under SAAs are subject to licensing by the Federal Aviation Administration (FAA). The Commercial Space Launch Act (51 U.S.C. § 50901, et. seq.) prescribes methods to indemnify the licensee for third-party liability arising during the licensed activities.

For future phases of commercial crew development, NASA's approach to allocating third-party liability between the Government and industry will be dependent on NASA's approach to FAA licensing, which is still under development. For any commercial launch and reentry activity that requires an FAA license, the Commercial Space Launch Act indemnification provisions will apply. For launch and reentry activities of NASA missions that do not require an FAA license, NASA intends to use contract provisions that match the intent of the FAA authority to limit third-party liability. Contract provisions similar to those used in NASA's Launch Services (NLS) contracts, which are commercial, may be incorporated into future CCP contracts to allocate liability, but this is still being reviewed.

Q2. (a) NASA is proposing the next phase of the Commercial Crew program to be a firm-fixed price procurement. As an experienced program manager do you believe that NASA's requirements in developing human spaceflight systems are mature enough for NASA's industry partners to bear all of the technical, safety, and schedule risks with a fixed-price contract?

Q2. (b) Given the track record of previous attempts to build a replacement for the Space Shuttle over the past 20 years, why is NASA so confident that the technical, safety, and schedule risks have been mitigated enough to allow for a firm-fixed price procurement?

A2 a. On December 15, 2011, NASA announced a modified competitive acquisition strategy designed to make the best use of available resources and to define the most cost effective path to the achievement of a commercial crew capability, as directed by Congress. Instead of transitioning to firm-fixed price contracts for the next phase of the Program, the Agency plans to continue to use multiple, competitively awarded funded Space Act Agreements (SAAs). Using competitively-awarded SAAs instead of contracts will allow NASA to maintain multiple partners during this phase of the Program, and provide NASA with the flexibility to adjust technical content and funding levels based on available funds. This new acquisition strategy will allow the Agency to preserve competition and maintain momentum to provide a U.S.-based commercial crew launch capability at the earliest possible time.

A2 b. NASA recently completed the baseline technical and safety requirements for a crew transportation system. The requirements documents are complete (i.e., there are no items yet "to be determined") and they reflect over two years of effort on the part of the Agency. There were several draft versions that were released to industry, and NASA received and addressed extensive comments to the earlier drafts. The requirements are publicly available at http://commercialcrew.nasa.gov/page.cfm?ID=28 for use by the commercial partners during the SAA phase. Thus, NASA believes that the requirements are sufficiently mature to enable the Agency to confidently enter the next phase of the Program.

Q3. Launch abort systems are one of the most critical and technically challenging features to design, integrate, and test. What are NASA's plans for verifying the performance of each company's systems? For instance, will they be required to successfully flight-test their launch abort systems?

A3. In future phases of the Commercial Crew Program, NASA will manage the crew transportation system certification process to ensure that commercial partners have met NASA requirements—including crew safety requirements—in their certification plans. Crew transportation system certifications will culminate with a successful mission to and from the International Space Station (ISS), or a comparable target. Results of a commercial partner's tests, analyses, demonstrations, and/or inspections

of spacecraft systems, including launch abort systems, will be formally evaluated to obtain NASA concurrence of the commercial partner's progress towards certification. To date, NASA has not dictated that a specific test program be followed for all crew transportation systems. Instead, NASA plans to evaluate the overall test program for each specific system.

Following the NASA determination of readiness, NASA will facilitate an Agency-level review to grant the commercial partners approval to transport NASA and NASA-sponsored personnel to the ISS, based on evidence of satisfactorily completing the crew transportation system certification.

It should be noted that, as part of its efforts to support the development of safe, reliable, commercial transportation systems, NASA has provided technical assistance to companies that participated in the Commercial Crew Development (CCDev) effort, and the Agency anticipates continuing to provide "lessons learned" information to its Commercial Crew Program partners.

Q4. What steps is NASA taking to coordinate requirements and regulations with the Federal Aviation Administration to ensure compatibility?

A4. Both NASA and the Federal Aviation Administration (FAA) envision a state where the FAA licenses commercial human spaceflights provided by a robust industry, from which the government and the private sector can purchase transportation services. The FAA has already developed and implemented processes and procedures for licensing and regulating commercial space activities to protect the safety of the public. Additional regulations for protection of crew safety are in development.

Although it is not a regulatory Federal agency like the FAA, NASA is responsible for assuring the safety of the public, as well as NASA crews/workforce and assets during NASA or NASA-sponsored space operations. In support of those responsibilities, NASA is currently developing the certification requirements and program processes for commercial transportation of NASA crews to the ISS.

The requirements and processes of these separate agencies must be carefully coordinated and aligned to assure that both agencies' roles are accomplished with thoroughness and rigor while remaining consistent in areas of mutual consideration. At the same time, it will be critical to the success of the industry ventures to minimize the burden of Government requirements and regulations imposed by multiple agencies. Early collaboration between NASA and the FAA during the formulation of requirements, certification processes and regulatory compliance processes will encourage an efficient and effective synergy between NASA and the FAA in the execution of their responsibilities.

In collaboration with the FAA, NASA has recently baselined the initial certification and operations requirements for the services it wishes to acquire from commercial providers. NASA will continue to partner with the FAA for the purposes of determining common standards and uniform processes to ensure both public safety and protection of cargo, crews, and spaceflight participants for the NASA-sponsored missions. NASA and the FAA will work towards minimizing the duplication of requirements, developing a streamlined process and addressing indemnification issues. This will be accomplished by clearly defining roles and responsibilities of each agency, sharing relevant data and jointly performing assessments to enable the commercial partner to be successful in support of missions with and without NASA-sponsored personnel. NASA and the FAA are in the process of documenting agreements that solidify each agency's commitment to this partnership.

Q5. According to the IG, NASA will not be "human rating" commercial systems that will fly NASA astronauts. Instead, the Agency is planning to "certify" commercial vehicles to carry NASA astronauts. What is the difference between "human rating" NASA vehicles and simply certifying commercial systems to carry NASA astronauts?

A5. The term 'human rating' is intentionally not used by NASA when referring to the certification of commercial systems because it implies a broader context of certification to fly any humans on any missions. NASA's current efforts to define a certification process only involve Agency-sponsored personnel on low Earth orbit (LEO) missions to the ISS. NASA will not be involved in the certification of commercial systems when they are used to transport non-Agency-sponsored personnel.

Question Submitted by Ranking Member Eddie Bernice Johnson

Q1. NASA has stressed the importance of competition as a means for achieving cost-effectiveness during development of the commercial crew systems.

- *If appropriated funding is only enough for one development contract, how much confidence can Congress have in the cost-effectiveness of that development plan, especially given NASA's critical need for the capability?*
- *Are you prepared to go forward in the event there is only one contractor at the end of the day? What, if any alternative, do you have?*
- *If there is only one contractor, you would be in effect setting up a monopoly in commercial crew transportation services. How comfortable would you be with that, and what does that mean for the ISS in the event of a launch failure from that single contractor?*

A1. NASA agrees that a key objective of the CCP is to maintain as many viable commercial vendors as possible in order to keep the cost of crew transportation services down and reduce the risk that U.S. astronauts might be grounded by a technical anomaly. The Agency's ability to fund more than one commercial crew provider is contingent upon the availability of appropriated funds. While the $406M for the Commercial Crew Program funded in the Consolidated and Further Continuing Appropriations Act of 2012 (P.L. 112–55) will enable the Agency to move the Program forward, NASA has had to reassess its acquisition strategy for this Program to maximize the effectiveness of limited resources.

On December 15, 2011, NASA announced a modified competitive procurement strategy designed to make the best use of available resources and to define the most cost effective path to the achievement of a commercial crew capability, as directed by Congress. Instead of transitioning to contracts for the next phase of the Program, the Agency plans to continue to use multiple, competitively awarded funded Space Act Agreements (SAAs). Using competitive SAAs instead of contracts will allow NASA to maintain a larger number of partners during this phase of the Program, and provide NASA with the flexibility to more easily adjust to various funding levels. This new acquisition strategy will allow the Agency to preserve competition and maintain momentum to provide a U.S.-based commercial crew launch capability at the earliest possible time.

This new strategy has resulted in an estimated availability date for U.S. commercial crew services likely by 2017. NASA's current exception to the Iran, North Korea, and Syria Nonproliferation Act (INKSNA) extends through June 2016. In order to procure transportation and rescue services using the Russian Soyuz spacecraft, the Agency will require modifications to INKSNA. Separate from the need for INKSNA relief for Soyuz crew transportation and rescue services, INKSNA relief will be needed for Russia-unique ISS goods and services for the life of the ISS Program. Given the lead-time required to manufacture Soyuz spacecraft, contractual arrangements for crew rotation and rescue for launch in the spring of 2016 should be in place by the spring of 2013. As NASA has testified, some modification of the INKSNA provisions will likely be required for the continued operation of ISS and other space programs after 2016. The Administration plans to propose appropriate provisions and looks forward to working with the Congress on their enactment.

NASA plans to procure U.S. commercial crew transportation and rescue services from one or more U.S. commercial providers, depending on funding availability. Having more than one domestic capability will provide the advantages of keeping costs low through competition, and ensuring that if one vendor's vehicle is grounded due to an anomaly, NASA would still retain a domestic option for the transport and rescue of its astronauts to the ISS. Having a contract in place with Russia, if we have the necessary INKSNA modification, would provide another layer of redundancy that would ensure that the Agency could meet its transportation obligations in the event of a commercial vendor stand-down in a single vendor scenario but this would force the program to again rely on foreign providers for transportation services.

The Agency believes that it will be able to fund multiple commercial crew transportation providers at least for the next phase of the program. Funding only a single provider would entail greater technical risks for the Agency and reduce the providers' incentive to keep the costs of crew transportation down. The GAO recently concluded that using competition for CCP was a "good practice" in its report, "Acquisition Approach for Commercial Crew Transportation Includes Good Practices but Faces Significant Challenges." (GAO 11–282). If NASA is limited to funding a single provider, the Agency will assess its options, risks, and resources availability to determine the feasibility and impacts of having a single U.S. provider. Adequate funding will be important to maintaining the ability to retain multiple providers.

Q2. How will the international partnership "certify" the crew rescue capability of commercial crew vehicles, or will certification be solely a NASA decision?

A2. It is NASA's responsibility to provide crew transportation and rescue capability for U.S., European, Japanese, and Canadian astronauts (the Russians are responsible for providing these capabilities for their cosmonauts). NASA is responsible for certifying the crew transportation and rescue capabilities of the commercial service providers from whom it procures services, though the Agency would keep the other ISS Partners apprised of its review. NASA responsibilities include assessment of compliance with the ISS Visiting Vehicles policy, thereby ensuring that the safety and integrity of the ISS will be maintained for all concerned parties.

Q3. I understand that the Phase 1 design contract will last approximately two years and that an RFP for the Phase 2 development contract could be issued about halfway into Phase 1. Please explain the rationale for issuing a development RFP when work on the design Phase is not complete? How does that approach meet the objective of reducing risk through a two-phase procurement strategy?

A3. NASA has recently re-assessed its approach to the Commercial Crew Program in light of available funding (please see response to question #1), so the phasing of the design and development work is under review. However, in general, the overlapping approach was adopted to reduce development risk while at the same time ensuring that the period between the retirement of the Space Shuttle and NASA's ability to send astronauts to the ISS aboard new U.S. vehicles was kept to a minimum, without sacrificing safety considerations.

Q4. How much weight will you give to a commercial proposer's business strategy when it comes time to award contracts for the initial design and later for the development of commercial crew systems to meet NASA's needs? Is a proposer's ability to obtain revenue from markets other than NASA ISS flights a requirement, and if so, by what timeframe?

A4. On February 7, 2012, NASA released an Announcement for Proposals (AFP) for the next phase in Commercial Crew development. The effort is known as Commercial Crew Integrated Capability (CCiCap). Proposals from industry will be due on March 23, 2012, and NASA expects to award multiple funded Space Act Agreements (SAAs) in the July/August timeframe. The overall CCiCap strategic goal is to advance multiple integrated commercial crew transportation system concepts to the stage of an orbital crewed demonstration flight capability as soon as possible while ensuring crew safety and considering potential customer standards.

NASA has been and will continue to refine its cost modeling capability to help understand potential crew transportation system development costs. In addition, NASA will evaluate the total government investment being requested by participants in their Commercial Crew Integration Capability (CCiCap) proposals to determine the effectiveness of their proposed approach and to establish a confidence factor for each company's likelihood of successful performance.

Q5. Witnesses on the first panel testified that should the ISS international partnership open up to other countries, there would be a possibility for an expanded market to provide services for the other partners who would then need access to the ISS. Have the international partners contemplated inviting new partners to the ISS? What would be involved in expanding the partnership? What would be entailed in allowing access to other potential partners? Does NASA have plans to seek an expanded partnership?

A5. Expanding the ISS partnership would entail significant multi-lateral negotiations, including extensive discussions on the allocation of Space Station crewing, resources, and research time. In addition, if a hypothetical new partner were to provide their own hardware or vehicle for use with the ISS, such equipment would need to be assessed and certified as being safe for use in or near the Station, and their systems would have to be compatible with those used aboard ISS. While the addition of new partners is a possibility, NASA and its current ISS partners have no plans to seek an expanded partnership at this time. However, the ISS partnership will continue enabling research opportunities for non-partner countries. Such participants are currently sponsored by an existing ISS partner.

Question Submitted by Representative Paul Broun

Q1. What obligations do companies have to report anomalies to NASA under space act agreements?

A1. Just like FAR-based contracts, there is no standard requirement that companies report anomalies to NASA under Space Act Agreements. However, a company may be required to report anomalies as part of its performance under a Space Act

Agreement if that obligation is negotiated between NASA and the company and included in the Space Act Agreement. For example, in order to receive a milestone payment for a demonstration mission under its COTS Space Act Agreement, SpaceX is required to provide NASA with an identification of any anomalies associated with the mission along with its preliminary assessment regarding the cause of the anomaly.

Q2. What information do you believe companies are obligated to provide NASA under a space act agreement?

A2. Just like FAR-based contracts, there is no standard requirement that companies report anomalies to NASA under Space Act Agreements. However, a company may be required to report anomalies as part of its performance under a Space Act Agreement if that obligation is negotiated between NASA and the company and included in the Space Act Agreement. For example, in order to receive a milestone payment for a demonstration mission under its COTS Space Act Agreement, SpaceX is required to provide NASA with an identification of any anomalies associated with the mission along with its preliminary assessment regarding the cause of the anomaly.

Q2. How long after an anomaly is detected, observed, or identified, do you believe a company is obligated to report such an anomaly to NASA under a space act agreement?

A2. If a Space Act Agreement includes a requirement for a company to report anomalies to NASA, the Space Act Agreement will also specify the time frame for the report. For example, if reporting anomalies is a requirement for a milestone payment then the report would be due at the same time other documentation is provided to NASA to support the milestone payment.

Q4. What obligation does a company have under traditional contracting to report anomalies to NASA?

A4. There is no standard contract requirement regarding anomaly reporting. When needed, a clause is tailored for the specific contract.

Under the previous acquisition strategy for the Commercial Crew Program, the Integrated Design Contract (IDC) would have required the Contractor to notify the Government of qualification or test anomalies involving the Crew Transportation System (CTS) design (e.g., launch and orbital vehicles, systems, subassemblies, components, software) and similar launch and orbital vehicles that might affect the CTS design. Under the contract, the Contractor would have been responsible for conducting any investigation of test anomalies and presenting any findings and proposed corrective actions to the Government. In addition, the Government would have had the right to conduct its own investigation of any anomaly. The Contractor would have been required to cooperate with any Government investigation and to allow the Government to observe and participate in any Contractor-led investigation.

Q5. What information do you believe a company is obligated to provide NASA under traditional contracting?

A5. Each contract includes data reporting and deliverable provisions as appropriate for the purpose and requirements of that contract. Under the IDC draft RFP, NASA identified the information to be provided by prospective Contractors through use of a Data Requirements List (DRL)/Data Requirements Description (DRD). This Data Requirements List (DRL) set forth the data requirements in each Data Requirements Description (DRD) describing the data required for the contract. There were fourteen (14) detailed DRL/DRDs contained in the draft RFP for IDC.

Q6. How long after an anomaly is detected, observed, or identified, do you believe a company is obligated to report such an anomaly to NASA under traditional contracting?

A6. NASA Policy Directive (NPD) 8621.1, for Mishap and Close Call Reporting, Investigating, and Recordkeeping, requires that Contractors notify NASA of anomalies within 24 hours. Anomalies that are classified as mishaps or high-visibility close calls must be reported to NASA telephonically as soon as practicable, and followed up within 24 hours in writing to HQs with detailed descriptions. These NPD reporting requirements were incorporated into the IDC contract as part of DRL CCIDC–S-001.

Q7. What obligation does a company have under the modified FAR acquisition to report anomalies to NASA?

A7. There is no standard contract requirement regarding anomaly reporting. When needed, a clause is tailored for the specific contract.

Under the previous acquisition strategy for the Commercial Crew Program, the Integrated Design Contract (IDC) would have required the Contractor to notify the Government of qualification or test anomalies involving the Crew Transportation System (CTS) design (e.g., launch and orbital vehicles, systems, subassemblies, components, software) and similar launch and orbital vehicles that might affect the CTS design. Under the contract, the Contractor would have been responsible for conducting any investigation of test anomalies and presenting any findings and proposed corrective actions to the Government. In addition, the Government would have had the right to conduct its own investigation of any anomaly. The Contractor would have been required to cooperate with any Government investigation and to allow the Government to observe and participate in any Contractor-led investigation.

Q8. What information do you believe a company is obligated to provide NASA under a modified FAR acquisition?

A8. Refer to answer provided for Question 5. Under the IDC solicitation, NASA used a more streamlined, commercial approach to limit the quantity of deliverables and reporting requirements while still ensuring NASA access and insight into information generated by the Contractor in performance of the contract.

Q9. How long after an anomaly is detected, observed, or identified, do you believe a company is obligated to report such an anomaly to NASA under modified FAR acquisition?

A9. NASA Policy Directive (NPD) 8621.1, for Mishap and Close Call Reporting, Investigating, and Recordkeeping, requires that Contractors notify NASA of anomalies within 24 hours. Anomalies that are classified as mishaps or high-visibility close calls must be reported to NASA telephonically as soon as practicable, and followed up within 24 hours in writing to HQs with detailed descriptions. These NPD reporting requirements were incorporated into the IDC contract as part of DRL CCIDC–S-001.

Q10. Please explain, in detail, the role of NASA's Safety and Mission Assurance Office in the design, development, construction, testing and acquisition of hardware associated with commercial crew services.?

A10. NASA's Office of Safety and Mission Assurance (OSMA) is governed by NASA Policy Directive (NPD) 1000.0A, the NASA Governance and Strategic Management Handbook and NASA Procedural Requirements (NPR) 7120.5, NASA Program and Project Management. For the Commercial Crew Program (CCP), as with other NASA programs, a Chief Safety and Mission Assurance Officer (CSO) has been assigned to carry out the roles of the SMA Technical Authority for CCP. The CSO reports independently through the Center SMA Director, the Center Director, and then to the Chief, OSMA.

OSMA, along with the other two NASA Technical Authorities and the Mission Directorate, were key contributors to, and are key stakeholders of, the Commercial Crew Transportation System Requirements Document (ESMD–CCTSCR–12.10). This document includes the appropriate set of safety, reliability, maintainability, and quality assurance policies, procedures, and requirements which must be met before NASA will certify a commercial provider to fly NASA or NASA-sponsored crew aboard their vehicle. Included are requirements and standards that govern the safety and mission assurance aspects of design, development, construction, and testing of commercial vehicles that will be used to transport NASA crew. The requirements defined herein must be met prior to flying NASA crew, regardless of the acquisition or procurement strategy followed.

As far as acquisition, the Chief, OSMA, is involved in NASA Acquisition Strategy and Procurement Strategy forums for each NASA Program. Currently, the strategy for CCP is for NASA to procure transportation services, not hardware. The services contract will include the mechanisms necessary for the appropriate amount of government insight needed to assure verification of the requirements in ESMD–CCTSCR–12.10. NASA will perform assessments to determine if the contractor has met all these requirements. If all requirements have been successfully met, NASA will grant CCTS Certification. If NASA cannot verify these requirements as having been met, NASA will not grant Certification.

Question Submitted by Representative Jerry Costello

Q1. What is NASA's backup plan if commercial crew systems are not available in the 2015–2016 timeline you anticipate? What contingency plan does NASA have for ensuring its requirements to service the ISS will still be met?

- *What will you do if there is an incident that requires a stand-down after you have started commercial crew flights? Will the Russians be willing and able to provide a backup crew transport capability without a crew transport contract extension already in place?*
- *At what point would NASA have to make a decision to extend its contract with the Russians for the use of Soyuz seats to transport NASA crews to the ISS, and what conditions would be required for NASA to make that decision?*

A1. While the $406M for the Commercial Crew Program (CCP) funded in the Consolidated and Further Continuing Appropriations Act of 2012 (P.L. 112–55) will enable the Agency to move forward with its plans to advance commercial services for crew transportation and rescue capabilities in support of the International Space Station (ISS), NASA has had to reassess its acquisition strategy for this Program.

On December 15, 2011, NASA announced a modified competitive procurement strategy designed to make the best use of available resources and to define the most cost effective path to the achievement of a commercial crew capability, as directed by Congress. Instead of transitioning to contracts for the next phase of the Program, the Agency plans to continue to use multiple, competitively awarded funded Space Act Agreements (SAAs). Using competitive SAAs instead of contracts will allow NASA to maintain a larger number of partners during this phase of the Program, and provide NASA with the flexibility to more easily adjust to various funding levels. This new acquisition strategy will allow the Agency to preserve competition and maintain momentum to provide a U.S.-based commercial crew launch capability at the earliest possible time.

This new strategy has resulted in an estimated availability date for U.S. commercial crew services likely by 2017. Thus, additional Soyuz purchases will be necessary to fill the gap until commercial crew becomes available. Fabrication of Soyuz vehicles must begin approximately 36 months prior to launch. Contractual arrangements for crew rotation and rescue services for launch in spring 2016 should be in place by spring 2013.

NASA's current exception to the Iran, North Korea, and Syria Nonproliferation Act (INKSNA) extends through June 2016. In order to procure transportation and rescue services using the Russian Soyuz spacecraft, and for Russia-unique ISS goods and services for the life of the ISS Program, the Agency will require modifications to INKSNA. Given the lead-time required to manufacture Soyuz spacecraft, contractual arrangements for crew rotation and rescue for launch in the spring of 2016 should be in place by the spring of 2013. As NASA has testified, some modification of the INKSNA provisions will likely be required for the continued operation of ISS and other space programs after 2016. The Administration plans to propose appropriate provisions and looks forward to working with the Congress on their enactment.

NASA plans to procure U.S. commercial crew transportation and rescue services from one or more U.S. commercial providers, depending on funding availability. Having more than one domestic capability will provide the advantages of keeping costs low through competition, and ensuring that if one vendor's vehicle is grounded due to an anomaly, NASA would still retain a domestic option for the transport of its astronauts to the ISS. Having a contingency contract in place with Russia, presuming appropriate INKSNA modifications, would provide another layer of redundancy that would ensure that the Agency could meet its transportation obligations in the event of a commercial vendor stand-down in a single vendor scenario but this would force the program to again rely on foreign providers for transportation services.

Q2. Do you envision commercial spaceflight participants to be sitting on the same commercial crew flights as NASA astronauts? Would including spaceflight participants add risks and liability concerns, and if so, what would NASA require of the commercial providers to mitigate those risks and liability concerns?

A2. It is a central part of NASA's CCP strategy that the commercial providers be able to sell human space transportation services to customers other than the Agency. Thus, NASA does envision the possibility that crew transportation system missions will include both NASA and non-NASA personnel at some point. There would need to be other agreements on the use of ISS resources if a commercial crew-

member wanted to visit the ISS. For example, the ISS partnership would likely require compensation for consumables and resources consumed or used by the commercial crewmember.

Including spaceflight participants on missions involving NASA personnel may add some unique risks to the flight, depending on the flight training and acceptance requirements of the spaceflight participants. Once those flight training and acceptance requirements have been established, NASA will be able to specifically address/mitigate any risk or liability concerns.

Q3. What is the plan for crew rescue vehicle stay time requirements at the ISS once NASA transitions to the use of commercially provided crew transportation to the ISS?

A3. NASA's requirements for crew rescue include the ability to rapidly and safely evacuate crewmembers from the ISS during a six-month Expedition, or "increment." Currently, this capability is provided by the Russian Soyuz spacecraft, which remains docked to the ISS for the entirety of a given increment, so that it is close at hand in the event of an anomaly which might require evacuation.

Requirements for commercially provided crew transportation systems were recently baselined by the Agency. The following are the relevant excerpts regarding crew rescue:

"3.1.2.2 Return Crew

The CTS shall return 1, 2, 3, and 4 NASA crew during a single entry/landing. [R.CTS.011] [I]

Rationale: Four NASA crew are required to be transported and returned to the ISS to meet the USOS demand for crew time based on full utilization of the ISS to perform science and support the ISS National Laboratory Program. All docking and undocking operations are a significant impact to the completion of ISS science, resulting in the determination by the ISS Program that the most efficient crew rotations strategy is to launch and return four crewmembers on a single vehicle. Additionally, the CTS must be able to accommodate one, two, three, or four crewmembers in a single launch or landing to provide flexibility in the ISS crew rotation plan. The spacecraft's secondary objective is to serve as the rescue vehicle for all personnel that were launched onboard and must have the capability to return all crewmembers in the event of an early mission termination or ascent abort.

3.1.2.3 Docked Duration

The CTS shall be capable of being docked to the ISS for 210 days to provide an assured crew return capability for four NASA crew. [R.CTS.012] [I]

Rationale: The ISS requires continuous presence of the spacecraft to support sustained operations. The 210 days provides 30 days of contingency on the nominal 180-day turnaround.

3.1.2.4 Rotation Intervals

The CTS shall be capable of exchanging up to four NASA ISS crewmembers every 150 to 210 days. [R.CTS.013] [I]

Rationale: The nominal crew rotation will occur at approximately 180 days based on the ISS human research program medical data collection needs. It is possible for this rotation to be altered by one month (earlier or later) in order to accommodate other overall ISS Program requirements or anomaly resolution/response."

Appendix II

Additional Material for the Record

ADDITIONAL MATERIAL FOR THE RECORD

Statement submitted by Representative Jerry Costello
Committee on Science, Space, and Technology,
U.S. House of Representatives

Mr. Chairman, thank you for holding today's hearing to receive testimony on the accomplishments and challenges of the National Aeronautics and Space Administration's (NASA's) Commercial Crew Development Program.

Since 2009, NASA has committed to developing a commercial crew system that utilizes innovation and entrepreneurship to build safe and affordable vehicles for transporting astronauts to and from low-earth orbit.

With the retirement of the Space Shuttle earlier this year, and NASA's contract for Russian crew services set to end in five years, commercial crew systems are an important part of human spaceflight's future and will ensure we fully utilize the International Space Station (ISS) through at least 2020.

While NASA's commercial crew development activities offer exciting opportunities for the future, these public-private partnerships represent a new approach to acquisition and human spaceflight that pose unique questions and challenges for the agency, its commercial partners, and Congress. I look forward to hearing how NASA and the six companies participating in the program are working together to ensure that the program remains efficient, cost-effective, and, most importantly, safe for our astronauts.

I look forward to hearing from our witnesses more about the progress made and the challenges that remain in achieving NASA's goal of a viable commercial system by 2016.

First, I would like to understand how confident NASA is in the cost and schedule estimates for achieving U.S. commercial crew services by about 2016 as well as the basis for those estimates. Second, I would like to understand what steps NASA and its commercial partners are taking to ensure that future U.S. commercial crew transportation systems are safe. Third, I would like to understand if there are trade-offs on risks given NASA's plans for a fixed government investment in the development of those systems.

I welcome our panel of witnesses and look forward to their testimony. I yield back the balance of my time.

ADDITIONAL MATERIAL FOR THE RECORD

Letter submitted by Representative Dana Rohrabacher, Committee on Science, Space, and Technology, U.S. House of Representatives

SPACE NEWS

Wed, 24 August, 2011

A Far Cry from a Commercial Approach

By Mike N. Gold

It's abundantly apparent to anyone trying to reverse America's embarrassing reliance on the Russian Federation for human spaceflight that this nation's problems have nothing to do with rockets, engines or technology in general. Companies such as Space Exploration Technologies have demonstrated that America still has the personnel and perseverance to make history with innovative, low-cost systems. However, there exists a force that no rocket is strong enough to escape from, and that is federal bureaucracy.

Often in our industry the question arises, what makes commercial crew "commercial"? If we limit this question to NASA's Commercial Crew Development (CCDev) program, the answer is quite simple: Commercial crew is a procurement practice. Specifically, a "commercial" procurement uses Space Act Agreements instead of the Federal Acquisition Regulation (FAR), operates on a fixed-price milestone basis instead of traditional cost-plus contracts and requires private sector investment so the companies have skin in the game.

This procurement strategy has been successfully implemented via the Commercial Orbital Transportation Services (COTS) program and the first two rounds of CCDev. In spite of how well this approach has worked and the inherent advantages to both participating companies and the taxpayer, it appears that NASA is on the verge of eliminating one of the key pillars that commercial space has been built upon, the Space Act Agreement.

For those unfamiliar with Space Act Agreements, this powerful legal vehicle basically allows NASA to take a clean-sheet approach to contracting with a potential commercial crew provider, avoiding the thousands of pages of dense regulations that come with a traditional FAR Part 35 contract. Even Congress recognized that it would be impossible to conduct low-cost innovative development and demonstration programs under the FAR, which is why NASA was granted broad authority to enter into Space Act Agreements.

The advantages of Space Act Agreements are many and varied. For example, in acknowledgement of private sector investment and the desire to create private sector capabilities, under a Space Act Agreement, participating companies are allowed to retain their intellectual property rights, preventing those properties from being handed over entirely to the government and potentially shared with competing corporations. This protection of proprietary intellectual property is critical for any company to invest its own dollars in such an effort.

Moreover, the question of control is a vital part of this debate. The inherent flexibility of Space Act Agreements provides a framework under which design decisions are made by the private sector company rather than being dictated by government overseers. The ability of commercial crew providers to make design decisions is at the very heart of what the commercial crew program is, since it frees companies from constant government change requests and thereby provides relief from what would otherwise be numerous layers of bureaucracy, which slows progress and raises costs.

In stark contrast to Space Act Agreements, the FAR is all about government control and requirements. The FAR is the literal embodiment of government regulations, and the adoption of a FAR-based approach would represent a fundamental shift in the balance of power away from commercial crew providers and back to NASA. This shift would alter the very nature of the commercial crew program in a fundamental and eventually fatal way.

Of equal or greater importance, the FAR costs money — lots of money — to implement. Even supporters of the FAR-based approach would acknowledge that implementing the FAR would mean a lot more red tape, which would require shifting funding away from engineers and hardware development in favor of accountants, auditors and attorneys to verify that the FAR's numerous and voluminous legal requirements have been adhered to, not only by participating commercial crew providers but by all of their subcontractors as well. For those who believe that we should spend more money on lawyers and less on launches, by all means, adopt the FAR. For those who are actually interested in success, I would argue that at a time when the commercial crew budget is already cut to a bare minimum, we can ill afford to spend more of our scant funds on bureaucracy.

Due to the problematic nature of the FAR (and there are many other challenges raised by the FAR that, in the interests of time and space, I have not addressed), after receiving feedback from industry, NASA acknowledged that at the very least a "hybrid" approach would have to be adopted, wherein the FAR's Cost Accounting Standards would be removed or revised in a future contract. While we appreciate the commercial crew office's attempt to address industry's concerns, I fear that it is a gross oversimplification to single out the Cost Accounting Standards and expect to succeed with the FAR, even if Cost Accounting Standards and intellectual property issues are resolved. The FAR is simply too long, too dense and too complex for all of its shortcomings to be rectified. This is why NASA was given the authority to enter into Space Act Agreements in the first place. Just identifying all of the ways that the FAR will impact CCDev would be difficult, and gaining legal permission to alter them all would be nearly impossible. Conversely, virtually anything from the FAR could be added to a Space Act Agreement without importing thousands of pages of irrelevant clauses that will create potentially dire unintended consequences.

To be clear, commercial crew providers arguing against the FAR are not zealots supporting Space Act Agreements out of ignorance or irrational bias. We at Bigelow Aerospace certainly believe that there is a time and place for the FAR, and that time and place is when development

and demonstration are complete. For example, we would wholeheartedly support a FAR Part 12 approach, which, unfortunately, I don't see as viable here since commercial crew systems are still in the development phase. Bigelow Aerospace would also vigorously support a bifurcated strategy under which development and demonstration would be performed via Space Act Agreement and the procurement under the FAR. Any experienced program manager would tell you that such an approach has great merit, since the character and pricing of a development program are very different from a procurement program. I strongly recommend that NASA take a second look at such an approach, particularly since it has worked so well for COTS and the Commercial Resupply Services programs.

It's also important for the space community to be aware that representatives of Bigelow Aerospace and other commercial space companies have discussed these substantive objections to the FAR with NASA officials and attorneys, and the push-back that we have heard time and time again is that NASA cannot levy requirements via a Space Act Agreement, a contention that we fundamentally disagree with. As a humanitarian, I will not recount the full legal argument here, but suffice it to say that the Government Accountability Office's (GAO) Rocket-plane Kistler decision supports the contention that so long as NASA's stated programmatic goal is to develop a private sector capability, Space Act Agreements can be utilized for commercial crew. An informal discussion I had with a GAO attorney has bolstered my belief in this position. Additionally, NASA's Office of Inspector General described a strategy wherein the agency could provide requirements to commercial crew providers that technically would not be mandatory but that any organization that wished to be eligible for future NASA service procurements would have to abide by. Both the GAO and the NASA Office of Inspector General appear to believe that the third round of CCDev could take place under a Space Act Agreement-based approach, which is why NASA's continued movement toward the FAR has justifiably led to frustration and cynicism among key CCDev participants.

Ultimately, Bigelow Aerospace's concern is the development of a domestic crew transportation system that can service both NASA and our own needs. As evidenced by the fact that knowledge of Cyrillic is now a necessary part of being a NASA astronaut, the old way of doing business has already failed. NASA cannot return to a traditional approach and expect anything but the traditional result, which for the past two decades has been a failure to produce a replacement for the space shuttle and bloated, broken budgets. For all of these reasons, I urge anyone, inside or outside of NASA, who wants to see America again fly its own astronauts to vigorously support the continued use of Space Act Agreements for CCDev.

Mike N. Gold is director of Washington operations and business growth for Bigelow Aerospace.

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