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

HEARING CHARTER

Ensuring the Safety of Human Space Flight

December 2, 2009
10 a.m. – Noon
2318 Rayburn House Office Building

I. Purpose

On December 2, 2009 the Subcommittee on Space and Aeronautics will hold a hearing focused on issues related to ensuring the safety of future human space flight in government and non-government space transportation systems. The hearing will examine (1) the steps needed to establish confidence in a space transportation system's ability to transport U.S. and partner astronauts to low Earth orbit and return them to Earth in a safe manner, (2) the issues associated with implementing safety standards and establishing processes for certifying that a space transportation vehicle is safe for human transport, and (3) the roles that training and experience play in enhancing the safety of human space missions.

II. Scheduled Witnesses:

Mr. Bryan D. O'Connor
Chief of Safety and Mission Assurance
National Aeronautics and Space Administration

Mr. Jeff Hanley
Program Manager
Constellation Program
Exploration Systems Mission Directorate
National Aeronautics and Space Administration

Mr. John C. Marshall
Council Member
Aerospace Safety Advisory Panel
National Aeronautics and Space Administration

Mr. Bretton Alexander
President
Commercial Spaceflight Federation

Dr. Joseph R. Fragola
Vice President
Valador, Inc.

Lt. Gen. Thomas P. Stafford, USAF (ret.)

III. Overview

The Review of U.S. Human Space Flight Plans Committee, also known as the Augustine committee, recently issued its final report. The committee was tasked to "*conduct an independent review of ongoing U.S. human space flight plans and programs, as well as alternatives, to ensure the Nation is pursuing the best trajectory for the future of human space flight—one that is safe, innovative, affordable, and sustainable. The review committee should aim to identify and characterize a range of options that spans the reasonable possibilities for continuation of U.S. human space flight activities beyond retirement of the Space Shuttle.*"

As directed, the committee's final report offered a number of options to the president for the conduct of future space exploration, ranging from continuing with the Constellation Program of Record (with slight modifications) to pursuing a "flexible path" with alternative launch vehicles, including modified Evolved Expendable Launch Vehicles (EELV) currently used primarily by the Department of Defense to transport military payloads. Several of the committee's options included the use of as-yet-to-be-developed commercial services to provide future crew transportation to and from the International Space Station (ISS) following retirement of the Space Shuttle. While the committee stated that it recognized both the risks and opportunities presented by commercial crew services, it believed such services could be available by 2016. Specifically, the report stated:

"The United States needs a way to launch astronauts to low-Earth orbit, but it does not necessarily have to be provided by the government. As we move from the complex, reusable Shuttle back to a simpler, smaller capsule, it is an appropriate time to consider turning this transport service over to the commercial sector. This approach is not without technical and programmatic risks, but it creates the possibility of lower operating costs for the system and potentially accelerates the availability of U.S. access to low-Earth orbit by about a year, to 2016. The Committee suggests establishing a new competition for this service, in which both large and small companies could participate."

Using commercial providers for space transportation is not a new idea. Congress has encouraged NASA to use commercial transportation services when appropriate as part of its space exploration strategy. Support for the commercial space industry was affirmed in P.L.110-422, the *National Aeronautics and Space Administration Authorization Act of 2008*. Along with that support however was a requirement for commercial services' prior conformance with NASA's safety requirements. Specifically, regarding crew

transportation, the Act stated in Sec. 902 that the National Aeronautics and Space Administration (NASA) shall:

" make use of United States commercially provided International Space Station crew transfer and crew rescue services to the maximum extent practicable, if those commercial services have demonstrated the capability to meet NASA-specified ascent, entry, and International Space Station proximity operations safety requirements."

Those NASA safety requirements are primarily embodied in NASA Procedural Requirements (NPR) document NPR 8705.2B, "*Human-Rating Requirements for Space Systems"* as well as in the ISS Visiting Vehicle requirements that govern proximity operations around the ISS. While the NPR requirements apply to the development and operation of crewed space systems developed by NASA and used to conduct NASA human spaceflight missions, the NPR also states that it *"may apply to other crewed space systems when documented in separate requirements or agreements"*.

Progress has been made in the past few years by commercial entities in designing and developing cargo launch capabilities which have the potential to access the ISS. However, they are not scheduled to demonstrate the capability to transport cargo to the ISS as part of NASA's Commercial Orbital Transportation Services (COTS) Demonstration project until the second quarter of Fiscal Year 2010, at the earliest. The transporting of NASA astronauts to low Earth orbit and ensuring their safe reentry to Earth is considered to be significantly more challenging than transporting cargo to the ISS.

That is the crux of the issue. Establishing and enforcing safety standards for the transport of crew on commercially provided orbital crew transportation services is in many ways uncharted territory. Furthermore, a process has yet to be advanced by the government on how the "airworthiness" of commercial space flight vehicles used to transport government passengers will be "certified" While the Augustine committee's report projected that commercial crew transportation services could be available in 2016, it does not appear that the committee's projection accounts for all of the milestones that must be met prior to the point at which NASA would be able to use such services to fly its astronauts to the ISS. Notionally, these include: prior Congressional authorization and appropriation of funds for such an activity, which could not occur before enactment of the FY 2011 appropriation for NASA at the earliest; agreement on human-rating and other safety standards and means for verifying compliance, development and implementation of new safety processes, testing and verification procedures to ensure safety, and potentially a new regulatory regime for certification; development of a COTS-like demonstration program open to multiple participants and competition/award of Space Act Agreements for the demonstration program; completion of the development/demonstration program, which would need to include a TBD number of demonstration flights, including tests of launch escape systems, etc.; subsequent preparation of an RFP for commercial crew transportation/ISS crew rescue services; contract competition, negotiation and award of contract(s), and potential protest(s) by losing bidder(s) [which unfortunately has become a more frequent occurrence in recent

Department of Defense (DoD)/NASA contract competitions]; manufacturing of the operational flight vehicle systems [some of which could potentially be initiated during the development/demonstration phase, assuming the companies would be able to fund those tasks with private capital]; TBD number of "certification" flights of the production vehicle system prior to NASA agreement to put its astronauts on board; and finally, commencement of initial operations to and from the ISS.

Any mismatch between the timetable asserted in the Augustine committee's report and the actual time required to bring commercially provided crew transportation services to operational status is relevant because it highlights a potential inability to meet even a fraction of NASA's crew transfer needs for the ISS prior to the end of even an extended ISS operations period [i.e., an ISS extension to 2020], which in turn calls into question the ability of would-be commercial providers to identify a credible government market when seeking private capital commitments. In the absence of a government commitment to pay for services whether or not they are available when needed, would-be commercial providers could face pressures to cut costs [or cease to compete], and the government would thus have to be vigilant to ensure that safety-related processes and practices were not compromised as a result.

Regardless of the approach to NASA's human space flight and exploration program that is recommended to Congress by the president, commercial space providers may well play an expanding role in transporting cargo to low Earth orbit (LEO) and eventually beyond LEO, and potentially transporting crew to and from LEO in the future. Consequently, it is prudent to initiate a detailed examination of the steps needed to establish confidence in commercial space transportation systems' capabilities to transport U.S. and partner astronauts to low Earth orbit and return them to Earth safely.

At the hearing, witnesses will provide a historical perspective on the establishment of safety requirements in NASA human space flight systems; NASA's efforts to develop human safety standards and requirements; the incorporation of crew safety requirements in the design of NASA's Constellation Program; and the commercial space transportation companies' expectations of how NASA's safety standards and requirements would be applied to commercial spacecraft as well as the level of governmental insight and oversight over their development activities and operations that they would consider appropriate.

IV. Issues

The hearing will focus on the following questions and issues:

- *What are the most important safety-related issues that need to be addressed in either a government or non-government space transportation system?*
- *What would be the safety implications of terminating the government crew transportation system currently under development in favor of relying on as-yet-to-be-developed commercially provided crew transportation services? What would the*

government be able to do, if anything, to ensure that no reduction in planned safety levels occurred as a result?

- *What expectations should Congress have regarding the safety standards commercial providers should meet if their proposed crew transportation and ISS crew rescue services were to be chosen by NASA to carry its astronauts to low Earth orbit? What would be required to verify compliance with those standards?*
- *If a policy decision were made to require NASA to rely solely on commercial crew transfer services, which would have to meet NASA's safety requirements to be considered for use by NASA astronauts, what impact would that have on the ability of emerging space companies to pursue innovation and design improvements made possible [as the industry has argued] by the accumulation of flight experience gained from commencing revenue operations unconstrained by a prior safety certification regime? Would it be in the interest of the emerging commercial orbital crew transportation industry to have to be reliant on the government as its primary/sole customer at this stage in its development?*
- *What lessons learned from the evolution of NASA's human space flight systems should be reflected in the design and operation of future crewed space transportation systems, whether government or non-government?*
- *What role does NASA's Office of Safety and Mission Assurance play in ensuring the safety of human space flight at NASA? What initiatives does the office have underway to enhance the safety of human space flight at NASA?*
- *What is being done to communicate NASA's safety and human-rating requirements to potential commercial crew space transportation and ISS crew rescue services providers?*
- *How and to what extent did safety considerations, especially with respect to launch, inform the choices made in NASA's Exploration Systems Architecture Study (ESAS)?*
- *How has the Constellation Program incorporated safety and applicable human-rating requirements, as well as Astronaut Office input on launch/entry systems safety, into the program's design, development, and testing activities?*
- *What has NASA learned so far in executing the Constellation Program that can assist in developing a better understanding of the impact of design features, development and testing and manufacturing processes, and operations procedures on the safety of crewed space transportation system alternatives?*
- *What are the expectations of potential commercial crew transportation services providers as to how safety standards and processes will be determined if the government decided to use commercial services for the transport of NASA astronauts to and from low Earth orbit and the ISS?*
- *What do potential commercial crew transportation services providers consider to be an acceptable safety standard to which potential commercial providers must conform if their space transportation systems were to be chosen by NASA to carry its astronauts to low Earth orbit and the ISS? Would the same safety standard be used for non-NASA commercial human transportation missions?*
- *What do potential commercial crew transportation services providers consider to be an acceptable level of insight and oversight over their development, test, and manufacturing process, their vehicles, and operations if their services are used to*

transport NASA astronauts to and from low Earth orbit and provide ISS crew rescue services?

- *What do potential commercial crew transportation services providers consider to be an acceptable certification regime that potential commercial services providers must comply with to address the government's regulatory responsibilities over the safety and "air worthiness" of commercial crew transportation vehicles prior to their approval for use in revenue-generating flight operations, whether for government or non-government customers?*
- *What training and familiarization with non-NASA crewed spacecraft and launch vehicles would astronauts flying on such non-NASA spacecraft and launch vehicles need in order to deal with off-nominal conditions, contingency operations and emergencies?*

V. Background

Relevant Legislation and Hearing on Safety Issues Associated with Commercial Space Launches

NASA Authorization Act of 2005

P.L. 109-155, the *National Aeronautics and Space Administration Authorization Act of 2005*, directed that an independent presidential commission be established to investigate incidents resulting in the loss of a U.S. space vehicle used pursuant to a contract with the Federal government or loss of a crew member or passenger in such a vehicle. The Act made clear that Congress believed that an accident involving astronauts riding on a commercial vehicle would be treated as at least as serious a matter as one involving a government vehicle. Specifically, the Act specified:

"(a) ESTABLISHMENT.—The President shall establish an independent, nonpartisan Commission within the executive branch to investigate any incident that results in the loss of—

(1) a Space Shuttle;
(2) the International Space Station or its operational viability;
(3) any other United States space vehicle carrying humans that is owned by the Federal Government or that is being used pursuant to a contract with the Federal Government; or
(4) a crew member or passenger of any space vehicle described in this subsection.

(b) DEADLINE FOR ESTABLISHMENT.—The President shall establish a Commission within 7 days after an incident specified in subsection (a)."

The independent commission would be tasked, to the extent possible, to investigate the incident; determine the cause of the incident; identify all contributing factors to the cause of the incident; make recommendations for corrective actions; providing any additional

findings or recommendations deemed by the Commission to be important; and prepare a report to Congress, the president, and the public.

NASA Authorization Act of 2008

The Congress affirmed its support for the commercial space industry in P.L.110-422, the *National Aeronautics and Space Administration Authorization Act of 2008*. The Act states in its findings that

"Commercial activities have substantially contributed to the strength of both the United States space program and the national economy, and the development of a healthy and robust United States commercial space sector should continue to be encouraged."

With regards to the potential use of commercially-provided ISS crew transfer and crew rescue services, the Act states that NASA may make use of commercial services if those commercial services have demonstrated the capability to meet NASA's safety requirements. Specifically, the Act states:

> *"(a) IN GENERAL.—In order to stimulate commercial use of space, help maximize the utility and productivity of the International Space Station, and enable a commercial means of providing crew transfer and crew rescue services for the International Space Station, NASA shall—*
>
> *(1) make use of United States commercially provided International Space Station crew transfer and crew rescue services to the maximum extent practicable, if those commercial services have demonstrated the capability to meet NASA-specified ascent, entry, and International Space Station proximity operations safety requirements;*
>
> *(2) limit, to the maximum extent practicable, the use of the Crew Exploration Vehicle to missions carrying astronauts beyond low Earth orbit once commercial crew transfer and crew rescue services that meet safety requirements become operational;*
>
> *(3) facilitate, to the maximum extent practicable, the transfer of NASA-developed technologies to potential United States commercial crew transfer and rescue service providers, consistent with United States law; and*
>
> *(4) issue a notice of intent, not later than 180 days after the date of enactment of this Act, to enter into a funded, competitively awarded Space Act Agreement with 2 or more commercial entities for a Phase 1 Commercial Orbital Transportation Services crewed vehicle demonstration program."*

However, with respect to subsection (4) above, the 2008 Act also made clear in Sec. 902(b) that:

> *"(b) CONGRESSIONAL INTENT.—It is the intent of Congress that funding for the program described in subsection (a)(4) shall not come at the expense of full funding of the amounts authorized under section 101(3)(A), and for future fiscal years, for*

Orion Crew Exploration Vehicle development, Ares I Crew Launch Vehicle development, or International Space Station cargo delivery."

Government Indemnification for Commercial Space Launch Operations

In 1988, Congress amended the *Commercial Space Launch Act of 1984* to indemnify the commercial space launch industry against successful claims by third parties. Specifically, the United States agreed, subject to appropriation of funds, to pay third party claims against licensees in amounts up to $1.5 billion [in 1989 dollars] above the amount of insurance that a licensee carries. The Act's definition of "third party" excludes all government employees, private employees, and contractors involved directly with the launch of a vehicle.

The Act requires that private launch companies purchase sufficient liability insurance. This amount is determined by the Federal Aviation Administration (FAA) on a case-by-case basis depending on its calculation of the "maximum probable loss" from claims by a third party. This amount is capped at $500 million for coverage against suits by private entities.

Since the majority of commercial launch activity occurs at federal launch ranges, the Act also requires any insurance policy a company obtains to also protect the federal government, its agencies, personnel, contractors, and subcontractors. The liability insurance section of the Act requires reciprocal waivers of claims between the licensee and its contractors, subcontractors, and customers. In effect, the licensee and any other organization assisting in the actual launch are prevented from seeking damages from one another. The indemnification and liability regime was first established by Congress as part of the Commercial Space Launch Act Amendments of 1988 and has been extended four times since its original enactment. On October 20, 2009, the U.S. House of Representatives passed H.R. 3819, a bill to extend the commercial space transportation indemnification and liability regime, by a voice vote. The liability risk-sharing regime extension is set to expire at the end of the year; H.R. 3819 would extend it for three more years. Congress has not yet explicitly addressed the issues of indemnification and liability for future commercially provided orbital human space flight services.

Commercial Space Launch Amendments Act of 2004

The Commercial Space Launch Amendments Act of 2004 put an initial regulatory framework in place for commercial human space flight. The intent of the law was to support the development of this private sector effort while also protecting the safety of uninvolved public on the ground. The law established an "informed consent" regime for carrying space flight crew and participants (passengers). The Act also created a new experimental launch permit for test and development of reusable suborbital launch vehicles. The 2004 law called for FAA to "*encourage, facilitate, and promote the continuous improvement of the safety of launch vehicles designed to carry humans*." To allow the industry to grow and innovate, the Act stated that "*Beginning 8 years after the date of enactment of the Commercial Space Launch Amendments Act of 2004, the*

Secretary may propose regulations" pertaining to crew and passengers, further adding that "*Any such regulations shall take into consideration the evolving standards of safety in the commercial space flight industry*." The eight year period [which ends in 2012] reflected the view that by then, the commercial human space flight industry would be "*less experimental.*"

As part of the "informed consent" regime, FAA regulations require an operator to inform in writing any individual serving as crew that the United States Government has not certified the launch vehicle and any reentry vehicle as safe for carrying flight crew or space flight participants. Similarly, the operator must inform each space flight participant in writing about the risks of the launch and reentry, including the safety record of the launch or reentry vehicle type. The "informed consent" rules became effective in December 2006.

FAA's subsequent rules call for launch vehicle operators to provide certain safety-related information and identify what an operator must do to conduct a licensed launch with a human on board. The protocols also include training and general security requirements for space flight participants. As part of the new measures, launch providers must also establish requirements for crew notification, medical qualifications, and training, as well as requirements governing environmental control and life-support systems. An operator must also verify the integrated performance of a vehicle's hardware and any software in an operational flight environment before carrying a space flight passenger. However, in issuing operator licenses, FAA does not certify the launch vehicle as safe as the agency customarily does with aircraft. In the latter case, the agency's Office of Aviation Safety provides initial certification of aircraft and periodically inspects an aircraft and certifies it as safe to fly. With regards to spacecraft, FAA can also issue experimental permits for launches of reusable vehicles conducted for research and development activities related to suborbital flight, for demonstrations of compliance with licensing requirements, or for crew training before obtaining a license.

2003 Joint Hearing on Commercial Human Space Flight

The Subcommittee and the Senate's Subcommittee on Science, Technology, and Space of the Committee on Commerce, Science and Transportation held a hearing entitled *Commercial Human Space Flight* in July 2003. Among the issues discussed at the joint hearing were when revenue launches would begin to happen, "what is safe enough", and whether the government should certify the safety of commercial vehicles prior to the commencement of passenger-carrying operations.

At the 2003 hearing, Senator Sam Brownback asked the witnesses when they could take their first commercial paying human customer into space. Mr. Jeff Greason, President of XCOR Aerospace said:

"That depends, in part, on factors that are not entirely in my control, like how fast we lock up some of the remaining investment. But if the investment is in hand, not sooner

than about three years, because we have an extensive test program we have to go through."

In response to Senator Brownback's question, Mr. Elon Musk, the CEO of Space Exploration Technologies, said:

"Well, the task that SpaceX has set for itself is probably an order of magnitude greater than sub-orbital flight. We've really aimed at orbital flight, really essentially the job that the Space Shuttle does. That's a longer road. But I think it's conceivable we could get something done in the 2006 time frame, as well."

With regards to safety, then-Subcommittee Ranking Member Bart Gordon asked Mr. Greason "*What is safe enough, and who should verify that*?" Mr. Greason replied:

"I mean, it's safe enough when the customers start to show up, and you go through a process of demonstrating the vehicle over and over and over again. Now, we have our own internal business targets about how safe we have to know it is before we can base a business on it. But it's important to realize that long before we get to the point where we know it's safe enough that our expensive asset won't crash and be lost to revenue service, something we have to do for our own business, long before that point, we will have demonstrated safety far superior to what people think of as space flight safety as being right now. I mean, the test program, alone is probably going to be 50 flights."

In a response to a question for the record posed by then-Subcommittee Chairman Dana Rohrabacher to Mr. Dennis A. Tito, CEO of Wilshire Associates, Inc, on what features of current aircraft standards and space launch safety standards should be applied to commercial human space flight, Mr. Tito provided the following response:

"As I stated in my testimony, commercial aviation is a mature and well-established industry. Aircraft safety standards reflect 100 years of powered flight experience, and are part of a 75+ year history of federal regulation increasingly focused on protecting the safety of airline passengers as well as uninvolved third parties. The commercial space launch industry is a somewhat less mature industry, with just over two decades of commercial experience. This industry's heritage, however, is based on over a half-century of military and civilian development and testing of ballistic missiles and their descendant launch vehicles. Missiles and most current launch vehicles have significant destructive potential and, because they are expendable, cannot be flight tested, fixed, and re-tested in the way aircraft or other reusable systems can. Launch safety standards have therefore focused on detailed oversight, complex system redundancy and flight termination (self-destruct) capabilities. Neither of these two operational safety paradigms is appropriate for commercial human space flight. There may be some similarities between aircraft and sub-orbital reusable launch vehicles, and others between RLVs [Reusable Launch Vehicles] *and expendable rockets. However, I predict that these new space planes will in fact merit their own operational safety approaches. At this point, we need to develop and fly some vehicles so we can learn what to do and what not to do. That, after all, is the beauty of the competitive marketplace:*

better ideas are rewarded while less-good approaches suffer until they are improved or die off."

Responding to a similar question for the record by Mr. Gordon on whether the government should certify the safety of his vehicles prior to commencement of passenger-carrying operations, Mr. Greason replied:

"The government should absolutely not certify the safety of our vehicles prior to the commencement of commercial, passenger-carrying operations. Today, we have a gap of one-million-to-one between the safety of space flight (roughly 40 fatalities per thousand emplanements for U.S. space missions) and aircraft (roughly 25 fatalities per billion emplanements for U.S. scheduled air carriers). When aviation started, its accident rate was as bad or worse than today's space transportation technology. In the early days, carrying passengers for ''barnstorming'' was one of the few sources of revenue in the aircraft industry. Today, risk tolerance is lower than in the 1920s. We believe we can and must do better. But if commercial RLV operators are ten times safer than government space flight efforts (which may be achievable), that is still 100,000 times less safe than aircraft. We are clearly too early for any kind of certification regime as that practiced in commercial aviation.

Early generation RLVs should be allowed to fly as long as the uninvolved general public are kept reasonably safe. The key is a system which investigates failures and shares the methods used successfully. The best and fastest path to safety is establishing a regulatory culture of continuous improvement based on experience; and the more flights we get, the faster we will gain that experience. Attempts to shortcut this process by establishing standards based on guesses or predictions about future technologies will stifle innovation, fix in place present practices, and slow the pace of safety improvement. This might not be so bad if the current safety record of space transportation were something to preserve. But it is not; it is something to change for the better."

"The current safety situation will change when operational track records are established. It is very likely that there will be dramatic differences in safety between vehicle types. When that happens, AST, industry, and the NTSB need to collaborate on raising the bar, perhaps by establishing minimum safety records, perhaps by design standards, or a mix of both. As this evolves, it will be important to avoid applying these new regulations to vehicle test flights. Research and development test flights should continue with the sole burden of protecting the safety of the general uninvolved public. In this way we can hope that people will look back on the first century of private space flight and see the same dramatic improvement in safety which has been demonstrated by aircraft."

In addition to illuminating the discrepancy between the schedule predictions of the emerging commercial providers and their actual performance to date, the testimony cited above raises the policy issue of the potential impact of a decision to require NASA to rely on commercially provided crew transportation services, which would have to meet NASA's safety requirements prior to NASA having its astronauts utilize those services. Given that the emerging commercial providers appear to believe strongly in an

evolutionary approach to design and safety innovation to be achieved through flight experience gained from revenue flights undertaken without any prior safety certification regime, premature reliance on the government as the dominant/only customer would call into question the ability of the emerging commercial providers to sustain the approach to innovation that they appear to believe is essential to their long-term success.

NASA's Incorporation of Safety Measures into Its Human Space Flight Programs

Several key safety initiatives were undertaken by NASA following the experience gained from flight missions:

- In January 1986, the Space Shuttle *Challenger* and its crew were lost 73 seconds after launch because of the failure of a seal (an O-ring) between two segments of a Solid Rocket Booster. In response to the findings of the Rogers Commission that investigated the *Challenger* accident, NASA established what is now known as the Office of Safety and Mission Assurance (OSMA) at Headquarters to independently monitor safety and ensure communication and accountability agency-wide. The Office monitors "out of family" anomalies and establishes agency-wide Safety and Mission Assurance policy and guidance such as human-rating requirements to which NASA program managers must adhere. OSMA also reviews the Space Shuttle Program's Flight Readiness Process and signs the Certificate of Flight Readiness.

- In February 2003, Shuttle *Columbia* disintegrated as it returned to Earth. In the ensuing investigation by the *Columbia* Accident Investigation Board (CAIB), the CAIB found that *Columbia* broke apart from aerodynamic forces after the left wing was deformed from the heat of gases that entered the wing through a hole caused during launch by a piece of foam insulation that detached from the External Tank. The CAIB found that the tragedy was caused by technical and organizational failures and provided 29 recommendations.

  Then-NASA Administrator Sean O'Keefe requested that Lt. Gen. Thomas Stafford, U.S. Air Force (Ret.) assign his Task Force on International Space Station Operational Readiness to undertake an assessment of NASA's plans to return the Space Shuttle to flight. At that time, the Stafford Task Force was a standing body chartered by the NASA Advisory Council, an independent advisory group to the NASA Administrator. Lt. Gen. Stafford activated a sub-organization with Col. Richard O. Covey, U.S. Air Force (Ret.) leading the day-to-day effort of conducting an independent assessment of the 15 CAIB "return-to-flight" recommendations. As a result, the Return to Flight Task Group was chartered in July 2003. Over the next two years, using expertise from academia, aerospace industry, the federal government, and the military, the task group, with Lt. Gen. Stafford and Col. Covey as co-chairs, assessed the actions taken by NASA to implement the 15 CAIB return-to-flight recommendations plus one additional item the Space Shuttle Program assigned to itself as a "raising the bar" action. The task group conducted fact-finding activities, reviewed documentation, held public meetings, reported the status of its

assessments to NASA's Space Flight Leadership Council, and released three interim reports. The task group issued its final report (dated July 2005) on August 17, 2005.

Lt. Gen. Stafford will be a witness at the hearing and can provide insights into safety challenges associated with human space flight.

- Among the CAIB's recommendations was one for NASA to establish an independent Technical Engineering Authority responsible for technical requirements and all waivers to them. In response, NASA created the NASA Engineering and Safety Center's (NESC) whose mission is to perform value-added independent testing, analysis, and assessments of NASA's high-risk projects to ensure safety and mission success.

  According to NASA, rather than relieving NASA program managers of their responsibility for safety, the NESC complements the programs by providing an independent technical review. Additionally, NASA states that the NESC provides a centralized location for the management of independent engineering assessment by expert personnel and state of the art tools and methods for the purpose of assuring safety. The NESC Management Office is located at NASA Langley Research Center in Hampton Virginia, but the NESC has technical resources at all 10 NASA Centers and Headquarters, as well as partnerships with academia, industry and other Government organizations. These technical resources are pooled to perform NESC activities and services. Operationally, the NESC falls under the responsibility of NASA's Office of Safety and Mission Assurance.

- NASA said that it recognized the importance of capturing the lessons learned from the loss of *Columbia* and her crew to benefit future human exploration, particularly future crewed vehicle system design. Consequently, the Space Shuttle Program commissioned the Spacecraft Crew Survival Integrated Investigation Team (SCSIIT) to perform a comprehensive analysis of the accident, focusing on factors and events affecting crew survival; and to develop recommendations for improving crew survival for all future human space flight vehicles. The Team's final report was released in December 2008, although findings were shared within NASA during the 3-year effort. Some illustrative recommendations with regards to future space craft design were as follows:

  - "*Future spacecraft seats and suits should be integrated to ensure proper restraint of the crew in offnominal situations while not affecting operational performance. Future crewed spacecraft vehicle design should account for vehicle loss of control to maximize the probability of crew survival*."
  - *"Future vehicle design should incorporate an analysis for loss of control/breakup to optimize for the most graceful degradation of vehicle systems and structure to enhance chances for crew survival. Operational procedures can then integrate the most likely scenarios into survival strategies."*

- *"Future spacecraft crew survival systems should not rely on manual activation to protect the crew*."

The Constellation Program's design is in conformance with the Team's findings. For example, with regards to the recommendation listed above on crew restraint, the program has (a) outfitted the Orion seats with the latest innovations in seat and restraint systems for enhanced occupant protection; (b) implemented limb flail requirements and additional protections to ensure proper arm positioning to maintain control of the vehicle under high acceleration events; and (c) is designing suit and seat in an integrated fashion with the entire spacecraft.

Mr. Jeff Hanley, Program Manager of the Constellation Program, will be a witness at the hearing and can provide additional details on how that Program is incorporating safety and applicable human-rating requirements, as well as Astronaut Office input on launch/entry systems safety, into the Constellation program's design, development, and testing activities.

NASA's Human Rating and Safety Requirements

According to NASA's Inspector General, NASA assembled a diversified group in 2007 composed of astronauts, engineers, safety engineers, flight surgeons, and mission operations specialists to rewrite the agency's human-rating requirements, which had been embodied in NPR 8705.2A, "Human-Rating Requirements for Space Systems." As stated in the NASA Inspector General's report IG-09-016 dated May 21, 2009:

"This group reviewed human-rating documents from the last 45 years that were used in the development of Mercury, Gemini, Apollo, Skylab, the Space Shuttle, and the International Space Station. The lessons learned from these programs, and information from numerous books and studies, resulted in NPR 8705.2B, issued May 6, 2008."

The stated purpose of NPR 8705.2B is "*to define and implement the additional processes, procedures, and requirements necessary to produce human-rated space systems that protect the safety of crew members and passengers on NASA space missions*."

The NPR states that "*a human-rated system accommodates human needs, effectively utilizes human capabilities, controls hazards and manages safety risk associated with human spaceflight, and provides, to the maximum extent practical, the capability to safely recover the crew from hazardous situations. Human-rating is not and should not be construed as certification for any activities other than carefully managed missions where safety risks are evaluated and determined to be acceptable for human spaceflight."*

The NPR further states that "*Human-rating must be an integral part of all program activities throughout the life cycle of the system, including design and development; test*

and verification; program management and control; flight readiness certification; mission operations; sustaining engineering; maintenance, upgrades, and disposal."

As to applicability, the NPR states that "*The human-rating requirements in this NPR apply to the development and operation of crewed space systems developed by NASA used to conduct NASA human spaceflight missions. This NPR may apply to other crewed space systems when documented in separate requirements or agreements*." The NPR notes that "*The Space Shuttle, the International Space Station (ISS), and Soyuz spacecraft are not required to obtain a Human-Rating Certification in accordance with this NPR. These programs utilize existing policies, procedures, and requirements to certify their systems for NASA missions*." The NPR is applicable to the Constellation Program.

The NPR views human-rating as consisting of three fundamental tenets:

1. Human-rating is the process of designing, evaluating, and assuring that the total system can safely conduct the required human missions.
2. Human-rating includes the incorporation of design features and capabilities that accommodate human interaction with the system to enhance overall safety and mission success.
3. Human-rating includes the incorporation of design features and capabilities to enable safe recovery of the crew from hazardous situations.

According to NASA's guidance, human-rating is an integral part of all program activities throughout the life cycle of the system, including design and development; test and verification; program management and control; flight readiness certification; mission operations; sustaining engineering; maintenance/upgrades; and disposal.

The NPR technical requirements for human-rating address system safety, crew/human control of the system, and crew survival/aborts. The requirements associated with crew survival and abort capability were established following the two previously cited Shuttle accidents. For example, the NPR states that for Earth Ascent Systems:

- *"The space system shall provide the capability for unassisted crew emergency egress to a safe haven during Earth prelaunch activities."*
- *"The space system shall provide abort capability from the launch pad until Earth-orbit insertion to protect for the following ascent failure scenarios (minimum list):*
    a. Complete loss of ascent thrust/propulsion
    b. Loss of attitude or flight path."
- *"The crewed space system shall monitor the Earth ascent launch vehicle performance and automatically initiate an abort when an impending catastrophic failure is detected."*

Regarding Earth ascent abort, the NPR states that:

- *"The space system shall provide the capability for the crew to initiate the Earth ascent abort sequence."*
- *"The space system shall provide the capability for the ground control to initiate the Earth ascent abort sequence."*
- *"If a range safety destruct system is incorporated into the design, the space system shall automatically initiate the Earth ascent abort sequence when range safety destruct commands are received onboard, with an adequate time delay prior to destruction of the launch vehicle to allow a successful abort."*

Once in orbit, the NPR requires the crewed space system to "*provide the capability to autonomously abort the mission from Earth orbit by targeting and performing a deorbit to a safe landing on Earth.*"

In addition, NPR 8715.3C which establishes NASA's General Safety Program Requirements, has a section entitled "*Hazardous Work Activities That Are Outside NASA Operational Control*." The NPR states that it is NASA policy to "*document and verify that risks are adequately controlled and any residual risk is acceptable*". Applicability to commercial human space flight is cited. Specifically, Section 1.14.1 states:

"It is NASA policy to formally review and approve NASA participation in hazardous work activities that are outside NASA operational control as needed to ensure that NASA safety and health responsibilities are satisfied. This policy applies unconditionally to NASA participation in commercial human spaceflight where current federal regulations do not necessarily provide for the safety of spaceflight vehicle occupants. This policy is non-retroactive and applies to hazardous ground or flight activities that involve research, development, test and evaluation, operations, or training, where all five of the following conditions exist:

> *a. NASA civil service personnel, Government detailees, specified contractors, or specified grantees are performing work for NASA.*
> *b. The activity is outside NASA's direct operational control/oversight.*
> *c. An assessment by the responsible NASA manager indicates there are insufficient safeguards and/or oversight in place.*
> *d. The activity is not covered by a basic contract, grant, or agreement where Federal, State, and/or local requirements address personnel safety.*
> *e. The nature of the activity is such that, if NASA were controlling it, a formal safety and/or health review would be required as part of the NASA approval process."*

In terms of responsibilities, the NASA Associate Administrator, as chair of the Agency Program Management Council, is the authority for human-rating and is responsible for certifying systems as human-rated. In this capacity, the NASA Associate Administrator makes the determination to certify a system as human-rated. Appeals for exceptions and waivers to the NPR are made to the NASA Associate Administrator. The Chief, Safety and Mission Assurance, is the Technical Authority for Safety and Mission Assurance and is responsible for assuring the implementation of safety-related aspects of human-rating.

In its 2008 Annual Report, the Aerospace Safety Advisory Board (ASAP), the congressionally established body which evaluates and provides advice on NASA's safety performance, noted changes in NPR 8705.2B from the prior guidance:

"The ASAP is concerned about HRR [human rating requirements] *substance, application, and standardization NASA-wide.*

- *After several briefings, the Panel is just beginning to fully understand the changes (e.g., in failure tolerance, inadvertent actions, redundancy, and integrated design analysis) and the implications for future system development—an index of the challenge facing NASA.*
- *The new HRR standards move from validating compliance with mandatory failure tolerance requirements to an approach of designing to acceptable risk, but without any apparent clear and visible criteria for estimating "how safe is safe enough" for various mission categories.*
- *A direct linkage between current standards and engineering directives is missing.*
- *NASA training materials on the new HRR standards are still in development and should be accelerated to distribute information before new Constellation systems are developed."*

Mr. Bryan O'Connor, Chief of Safety and Mission Assurance and former astronaut, will be a witness at the hearing and can provide additional details on OSMA's latest activities associated with implementing safety-related aspects of human-rating, including addressing the ASAP's concerns. Mr. John Marshall, a member of the ASAP, will also be testifying at the hearing.

Enhancing Safety through Crew Training

As evidenced by the performance of the crew of Apollo 13 after the incident that created a serious emergency situation en route to the Moon, astronauts play a major role in ensuring human safety in space. In that situation, the crew detected, reacted, and with the help of engineers and technicians on the ground, overcame problems that mechanical systems could not. Integral to that crew's ability to improvise under difficult conditions was the training they received.

Today's astronaut training program builds on years of flight experience. Once selected as candidates, astronauts undergo a rigorous training program that ranges from basic training in generic vehicle systems to being trained to operate spacecraft systems using simulators. Survival training includes emergency egress from the Shuttle and surviving in a water or wilderness environment. As a final step, crews conduct integrated operational training with flight controllers in NASA's Mission Control Center at the Johnson Space Center.

Training for off-nominal operations is an important facet of crew training. Astronauts are acquainted with non-safety-critical failure modes and the ways to respond to them.

Training for off-nominal conditions is primarily accomplished by inserting failures during simulations at which time astronauts are trained to recognize the off-nominal conditions and identify corrective measures. The level of difficulty arises when several failures are injected during simulations and crew members must perform failure analyses in an integrated manner and apply corrective procedures in sequence. Emergency training is needed for those situations where all measures identified through other forms of training cannot be used. The most critical emergencies primarily involve fire, depressurization, and toxic contamination. The goal of NASA's training is to have a trained astronaut who is able to respond and assist in any contingency situation that may arise.

Safety Considerations in NASA's Selection of Space Exploration Vehicles

In January 2004, President Bush announced his *Vision for Space Exploration*, which called for NASA to safely return the Space Shuttle to flight; complete the International Space Station (ISS); return to the Moon to gain experience and knowledge for human missions beyond the Moon, including Mars; and increase the use of robotic exploration to maximize our understanding of the solar system and pave the way for more ambitious human missions. Congressional support for a new direction in the Nation's human spaceflight program was clearly articulated in the 2005 NASA Authorization Act. Specifically, the Act directed the NASA Administrator "*to establish a program to develop a sustained human presence on the Moon, including a robust precursor program, to promote exploration, science, commerce, and United States preeminence in space, and as a stepping-stone to future exploration of Mars and other destinations. The Administrator was further authorized to develop and conduct appropriate international collaborations in pursuit of these goals*."

Shortly after Dr. Michael Griffin was named the new NASA Administrator in April 2005, he set out to restructure the Exploration Program by giving priority to accelerating the development of the Crew Exploration Vehicle (CEV) to reduce or eliminate the anticipated gap in U.S. human access to space following the retirement of the Space Shuttle. Specifically, he established a goal for the CEV to begin operation as early as 2011and to be capable of ferrying crew and cargo to and from the ISS. He also decided to focus on existing technology and proven approaches for exploration systems development. In order to reduce the number of required launches for exploration missions and to ease the transition after Space Shuttle retirement in 2010, the Administrator, consistent with the congressional guidance contained in the NASA Authorization Act of 2005, directed the Agency to examine the cost and benefits of developing a Shuttle-derived Heavy-Lift Launch Vehicle to be used in lunar and Mars exploration. As a result, the Exploration Systems Architecture Study (ESAS) team was established to determine the best exploration architecture and strategy to implement these changes.

In November 2005, NASA released the results of the ESAS, an initial framework for implementing the VSE and a blueprint for the next generation of spacecraft to take

humans back to the Moon and on to Mars and other destinations. ESAS made specific design recommendations for a vehicle to carry crews into space, a family of launch vehicles to take crews to the Moon and beyond, and a lunar mission "architecture" for human lunar exploration. ESAS presented a time-phased, evolutionary architectural approach to returning humans to the Moon, servicing the ISS after the Space Shuttle's retirement, and eventually transporting humans to Mars. Under the 2005 ESAS plan, a Crew Exploration Vehicle (CEV and now called Orion) and Crew Launch Vehicle (CLV and now called Ares I) development activities would begin immediately, leading to the goal of a first crewed flight to the ISS in 2011. Options for transporting cargo to and from the ISS would be pursued in cooperation with industry, with a goal of purchasing transportation services commercially. In 2011, the development of the major elements required to return humans to the Moon would begin—the lunar lander (now called Altair), heavy lift cargo launcher (now called Ares V), and an Earth Departure Stage vehicle. These elements would be developed and tested in an integrated fashion, with the internal goal of a human lunar landing in 2018. When resources needed to achieve the 2011 goal for CEV operations were not forthcoming, the Constellation Program established a formal target of 2015 for initial CEV flights to the ISS.

According to the ESAS report, the team's major trade study was a detailed examination of the relative costs, schedule, reliability, safety, and risk of using DoD's Evolved Expendable Launch Vehicle (EELV) and Shuttle derived launchers for crew and cargo missions. Among its operational ground rules and assumptions was the CAIB finding on the desirability of an architecture that will "*separate crew and large cargo to the maximum extent practical*".

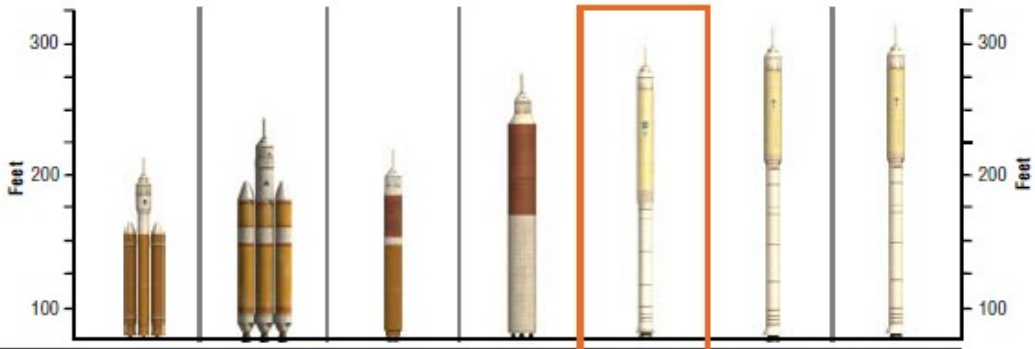
The EELV options examined for suitability for crew transport by the ESAS team were derived from the Delta IV and Atlas V families. The team found that:

- None of the medium versions of either vehicle had the capability to accommodate CEV lift requirements. Augmentation of the medium-lift class systems with solid strap-on boosters was thought by the team to pose an issue for crew safety because of small strap-on Solid Rocket Motor reliability.
- Both vehicles required modification for human-rating, particularly in the areas of avionics, telemetry, structures, and propulsion systems.
- Both Atlas- and Delta-derived systems required new upper stages to meet the lift and human rating requirements.
- Both Atlas and Delta single-engine upper stages fly highly lofted trajectories, which can produce high deceleration loads on the crew during an abort an, in some cases, can exceed crew load limits as defined by NASA standards.

CLV options derived from Shuttle elements focused on the configurations that used a Reusable Solid Rocket Booster (RSRB), either as a four-segment version nearly identical to the RSRB flown today or a higher-performance five-segment version of the RSRB. The team sought to develop options that could meet the lift requirement using a four-segment RSRB. To achieve this, a 500,000-lbf vacuum thrust class propulsion system would be needed. Two types of upper stage engines were assessed. According to ESAS,

the option chosen, including using the Space Shuttle Main Engine (SSME) for the upper stage, was selected due to projected lower cost, higher safety/reliability, its ability to utilize existing human-rated systems and infrastructure and the fact that it gave the most straightforward path to a heavy lift launch vehicle for cargo. Subsequently, to achieve lower recurring costs, the rocket motor powering the upper stage was changed to a variant of the J-2S Saturn-era motor and now called J-2X.

The following chart from the ESAS report summarizes the team's findings with regards to CLV options and compares these options on the basis of Loss of Mission (LOM) and Loss of Crew (LOC) probabilities:



	Human-Rated Atlas V/New US	Human-Rated Delta IV/New US	Atlas Phase 2 (5.4-m Core)	Atlas Phase X (8-m Core)	4 Segment RSRB with 1 SSME	5 Segment RSRB with 1 J–2S	5 Segment RSRB with 4 LR–85
Payload (28.5°)	30 mT	28 mT	26 mT	70 mT	25 mT	26 mT	27 mT
Payload (51.6°)	27 mT	23 mT	25 mT	67 mT	23 mT	24 mT	25 mT
DDT&E*	1.18**	1.03	1.73**	2.36	1.00	1.3	1.39
Facilities Cost	.92	.92	.92	.92	1.00	1.00	1.00
Average Cost/Flight*	1.00	1.11	1.32	1.71	1.00	.96	.96
LOM (mean)	1 in 149	1 in 172	1 in 134	1 in 79	1 in 460	1 in 433	1 in 182
LOC (mean)	1 in 957	1 in 1,100	1 in 939	1 in 614	1 in 2,021	1 in 1,918	1 in 1,429

LOM: Loss of Mission LOC: Loss of Crew US: Upper Stage RSRB: Reusable Solid Rocket Booster

* *All cost estimates include reserves (20% for DDT&E, 10% for Operations), Government oversight/full cost; Average cost/flight based on 6 launches per year.*

** *Assumes NASA has to fund the Americanization of the RD–180. Lockheed Martin is currently required to provide a co-production capability by the USAF.*

Source: NASA (ESAS)

With regards to crew safety, as shown in the table above, analysis by the ESAS team showed that the initially recommended concept had a mean LOC of 1 in 2,021 and the current design had a mean LOC of 1 in 1,918. As such, initially both concepts met the recommendations from the CAIB and the Astronaut's Office that a Shuttle replacement have at least a LOC of 1 in 1,000 missions. In comparison, the other options ranged from 1 in 614 to 1 in 1,100. The selected CLV design, which later became known as Ares I,

was also projected to offer significant improvement in Loss of Mission over other launch options.

In his presentation to the Augustine Committee on July 29, 2009, Dr. Joseph Fragola, a member of the ESAS team and Vice President of Valador, Inc., told the Committee that this meant that "*Ares I is at least a factor of 2 safer from a loss of crew perspective and in some cases closer to a factor of 3*." In a recent conversation between Subcommittee staff and Dr. Fragola, he indicated that the ESAS team was more interested in establishing the relative risk among the options and not in their absolute risk values. According to NASA, the recommended concept's lower LOC estimate is a direct reflection of the use of a simpler design and fewer moving parts characteristic of a single solid propellant first stage. The recommended concept was accepted and formed the basis of the Ares I crew launch vehicle.

Dr. Fragola will be a witness at the hearing and can provide additional details on the ESAS Team's analysis of how alternative configurations compared with regards to loss of crew and loss of mission projections.

Safety Oversight by the Aerospace Safety Advisory Panel

Since it was established in 1968 by Congress, the Aerospace Safety Advisory Panel (ASAP) has been evaluating NASA's safety performance and advising the agency on ways to improve that performance. The Panel consists of members appointed by the NASA Administrator and is comprised of recognized safety, management, and engineering experts from industry, academia, and other government agencies.

The ASAP reports to the NASA Administrator and Congress. The Panel was established by Congress in the aftermath of the January 1967 Apollo 204 spacecraft fire. The Panel's statutory duties, as prescribed in Section 6 of the NASA Authorization Act of 1968, Public Law 90-67, 42 U.S.C. 2477 are as follows:

"The Panel shall review safety studies and operations plans that are referred to it and shall make reports thereon, shall advise the Administrator with respect to the hazards of proposed operations and with respect to the adequacy of proposed or existing safety standards, and shall perform such other duties as the Administrator may request."

The Panel was authorized in Section 106, Safety Management, of the *National Aeronautics and Space Administration Authorization Act of 2005*, [P.L. 109-155]. The ASAP bases its advice on direct observation of NASA operations and decision-making. The Panel provides an annual report. In addition to examining NASA's management and culture related to safety, the report also examines NASA's compliance with the recommendations of the CAIB. Advice from the ASAP on technical authority, workforce and risk management practices has been provided to the NASA Administrator.

Critical human space flight safety issues the Panel identified in its 2008 Annual Report included the proposed extension of the Space Shuttle Program; the use of commercial transportation sources; the safety and reliability of the Russian Soyuz spacecraft; an opportunity to hardwire safety into the fabric of the Constellation Program**;** the suitability of agency management approaches; and technical Standards Program focused on safety and risks.

In his testimony at the Subcommittee's June 2009 hearing on "*External Perspectives on the FY 2010 NASA Budget Request and Related Issues"*, the ASAP witness stated that while the Panel endorses and supports investing in a Commercial Orbital Transportation Services (COTS) program, it believes "*at this juncture that NASA needs to take a more aggressive role articulating human rating requirements for the COTS Program since most programs are well underway. To do otherwise may, at a later time, pressure NASA into accepting a system for expediency that is below its normal standard for safety*". In its 2008 report, the ASAP stated:

"COTS vehicles currently are not subject to the Human-Rating Requirements (HRR) standards and are not proven to be appropriate to transport NASA personnel."

and

"The capability of COTS vehicles to safely dock with the ISS still must be demonstrated."

In addition to its annual report, the Panel submits Minutes with recommendations to the NASA Administrator resulting from its quarterly meetings. The Panel held its Third Quarterly Meeting in July 2009 [the Panel's most recent Quarterly Meeting was held on October 22, 2009 at the Kennedy Space Flight Center]. At that meeting, the Panel's official minutes referenced the panel's continuing concerns regarding the application of human rating criteria to commercial crew transportation services:

"*As far as the safety issues, they basically boil down to expanding the cargo capability to include crew. If that is done, the traditional method would be to apply full human rating criteria initially at the beginning of the program's development. However, thus far NASA has consciously chosen to not use a traditional approach, and there yet have been any performance requirements identified to put crews on board a COTS vehicle. The Panel previously had made a recommendation regarding this issue and continues to be perplexed as to why NASA has delayed this important action*."

"*The Panel has addressed its concern in its previous quarterly and annual reports. The issue is becoming more focused and more urgent. The prospect of a COTS delivery of cargo to space is organizationally and politically simpler than crew transport. The issue of human rating with COTS and the delivery of NASA astronauts into space is the primary concern. Admiral Dyer* [Chairman of the ASAP] *noted that the Panel remains concerned that in the probing of this question, NASA looks to the FAA, which doesn't have the institutional history and people to speak clearly to the topic. This issue represents an opportunity for improved interagency performance*."

Admiral Dyer also noted at the July meeting that *"If the* [commercial] *vehicle is being designed to be a cargo hauler, that is a different mission and a different set of designs than a crew transporter*." Mr. John Frost, a Panel member, added that "*the human rating requirements for the Agency are built around the design process and those processes are ongoing now at the COTS contractors. It would be problematic to come back later to put these requirements into a process that is already complete*."

As mentioned above, Mr. John Marshall, a member of the ASAP, will be a witness at the hearing and can provide additional details on the Panel's work and safety-related concerns.

Commercially Provided Crew and Cargo Space Transportation Services

At present there are no commercially owned and operated human space transportation systems in service. Only one company, Scaled Composites, has successfully launched and returned humans safely to space and back on suborbital flights in an experimental spacecraft [SpaceShipOne] and launch system. Virgin Galactic intends to purchase operational vehicles from Scaled Composites and enter into commercial operations. Originally slated to enter into commercial operations in 2007, they are currently projecting a 2011 debut for SpaceShipTwo's suborbital flight operations. Several other companies/ventures also have plans to take paying passengers on suborbital 'tourism' trips, but have not yet flown any craft to space with humans aboard.

Along with space tourism, the 'NewSpace' community has stated that suborbital services will be able to provide opportunities for suborbital science experiments, suborbital travel and package delivery. According to members of this 'Newspace' community, after carrying out suborbital business operation, a number of them have hopes of being able to undertake orbital operations in the future. However, there are a number of regulatory concerns and technical issues that would have to be addressed, as well as significant investments made, before such a future could be realized. Orbital flight operations are considered significantly more challenging than suborbital flight operations.

Commercial Orbital Transportation Services Demonstrations

Under the Commercial Orbital Transportation Services (COTS) Demonstration project, NASA is helping industry develop and demonstrate cargo space transportation capabilities. According to NASA, the COTS project provides a vehicle for industry to lead and direct its own efforts with NASA providing technical and financial assistance. NASA will invest approximately $500 million toward cargo space transportation flight demonstrations. There are currently two funded participants in the COTS demonstration project, namely Space Exploration Technologies (SpaceX) and Orbital Sciences Corporation (Orbital).

According to NASA, as of September 16, 2009, SpaceX had completed 15 of 22 milestones and has received a total of $243 million in payments, with $35 million available for the remaining milestones. Milestone tasks range from Project Plan Review to Flight Demonstration. SpaceX has begun manufacturing the flight Dragon capsule and Falcon 9 launcher to be used for the COTS demonstration flight 1. Under the terms of the current Space Act Agreement, SpaceX was scheduled to complete its first demonstration flight in June 2009 (The initial Space Act Agreement between NASA and SpaceX was signed in August 2006 and called for a scheduled first demonstration flight by September 2008).

To allow additional time for Dragon and Falcon 9 manufacturing and testing programs, SpaceX indicated in June 2009 that it expected to complete its first demonstration flight in January 2010, with the second and third flights then planned for June 2010 and August 2010, respectively. However, making the first COTS demonstration flight in January 2010 will be challenging. According to an October 29th, 2009 Space News article, development of the Falcon 9 rocket — along with that of its smaller sibling, the Falcon 1 — has taken longer than SpaceX expected. The same Space News article reports that SpaceX's range request for the inaugural Falcon 9 flight made for February 2010 conflicts with another already approved launch. This is significant because of the relationship between the Falcon 9 inaugural flight and the first COTS demonstration flight. The first COTS flight must receive an FAA license before it is launched. In its June 2009 briefing to the Augustine Committee, SpaceX projected that the first COTS demonstration flight would occur 2 months after the inaugural Falcon 9 flight. The smaller Falcon 1, which is designed for transport of satellites to low Earth orbit and is not part of the COTS project, has encountered its share of developmental challenges. In July 2009, Falcon 1 successfully delivered the Malaysian RazakSAT satellite to orbit. Prior to a successful test flight in September 2008 at which time a dummy payload reached orbit, there had been three unsuccessful Falcon 1 flights, the first of which occurred in March 2006.

As of September 16, 2009, NASA says that Orbital has completed 10 of its planned 19 milestones and has received a total of $120 million to date with an additional $50 million available for future milestones. The Orbital demonstration flight is currently planned for March 2011 due to the company's decision to change its cargo transportation architecture from an unpressurized (external) cargo system to a pressurized (internal) cargo system. The initial Space Act Agreement signed in February 2008 had a scheduled first demonstration flight date of December 2010.

According to NASA, the agency will not pay for any milestone until the milestone is successfully completed per the Space Act Agreement and approved by the agency. Should a milestone be missed, NASA says that it will evaluate partner progress made and recommend future actions that are in the best interest of the government.

Commercial Resupply Services

In December 2008, NASA awarded contracts to two companies for the delivery of cargo to the ISS after the retirement of the Space Shuttle. The successful bidders for Commercial Resupply Services (CRS) contracts were Orbital and SpaceX, the two COTS demonstration program funded participants. NASA says that it awarded two contracts to mitigate the risk of being dependent on a single contractor. A protest lodged to the Government Accountability Office (GAO) in January 2009 by PlanetSpace, Inc, an unsuccessful bidder, was subsequently denied by GAO in April 2009.

The scope of the CRS effort includes the delivery of pressurized and/or unpressurized cargo to the ISS and the disposal or return of cargo from the ISS. In addition, there are non-standard services and special task assignments and studies that can be ordered to support the primary standard resupply service. NASA ordered 8 flights valued at $1.88 billion from OSC and 12 flights valued at $1.59 billion from SpaceX. According to NASA's press release announcing the contracts, the maximum potential value of each contract is $3.1 billion. Based on known requirements, the combined value of the two awards is projected at $3.5 billion.

Each award under the contracts calls for the delivery of a minimum of 20 metric tons of cargo to the ISS, as well as the return or disposal of 3 metric tons of cargo from the orbiting complex. The CRS contracts are firm-fixed price, Indefinite Delivery Indefinite Quantity procurements with a period of performance from January 1, 2009, through December 30, 2015.

Commercial Crew Transportation Services

Although NASA currently has no contracts for the transportation of crew by commercially provided space transportation services [which do not at present exist], it has recently applied funds from the American Recovery and Reinvestment Act of 2009 to work on the Commercial Crew and Cargo Program:

- A modification to the Bioastronautics contract with Wyle Integrated Science & Engineering Group was made to develop a set of human system integration requirements for application to commercial spacecraft in support of NASA's Commercial Crew and Cargo Program. According to NASA, the human system integration requirements developed under this task order will be based on a review of existing Human Rating requirements, Spaceflight Human Systems Standards, Constellation Program requirements, Commercial Crew and Cargo Program Office operational concepts and requirements, and the Johnson Space Center Space Life Sciences Directorate Human Interface Design Handbook.

- NASA's Commercial Crew and Cargo Program is applying Recovery Act funds to solicit proposals from all interested U.S. industry participants to mature the design and development of commercial crew spaceflight concepts and associated enabling technologies and capabilities. NASA plans to use its Space Act authority to invest up

to $50 million dollars in multiple competitively awarded, funded agreements. This activity is referred to as Commercial Crew Development, or CCDev.

Commercial Spaceflight Federation

According to the Commercial Spaceflight Federation (CSF), its mission is to "*promote the development of commercial human spaceflight, pursue ever higher levels of safety, and share best practices and expertise throughout the industry. CSF member organizations include commercial spaceflight developers, operators, and spaceports*". The Commercial Spaceflight Federation is governed by a board of directors, composed of the member companies' CEO-level officers and entrepreneurs.

The Federation recently voiced strong support for the report by the Review of U.S. Human Space Flight Plans Committee which included in its options the creation of a Commercial Crew program to develop commercial capabilities to transport crew to the International Space Station.

Mr. Bretton Alexander, President of the Commercial Spaceflight Federation, will be a witness at the hearing and can provide details related to commercial provider plans to human rate commercial space transportation systems as well as the commercial space industry expectations of how NASA's safety standards and requirements would be applied to commercially crewed spacecraft.