Written Testimony of

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Thank you, Chairman Palazzo, Ranking Member Costello, and Full Committee Chairman Hall for that warm introduction, and to the Committee for the opportunity to once again express my personal views and concerns at this hearing to review the impacts of the recent Soyuz launch vehicle failure on the safe operation and utilization of the International Space Station (ISS). I will attempt to answer the questions provided in your letter of invitation from the standpoint of my position as the advisory committee chairman and former astronaut. As you all know, I have had the unique experience of working with the Russians during the era of the Soviet Union as a member of the Apollo-Soyuz Test Program. As an American astronaut, I joined with our Russian colleagues and was afforded an opportunity to view their space program up close alongside their best engineers and technicians. As a result of that successful joint program, NASA and ROSCOSMOS were able to join again to operate together in space with the Shuttle-MIR program culminating in our successful partnership on ISS. Throughout that long partnership, I continued to observe and assess the Russian space program and am delighted to share my thoughts.

If the proposed launch schedules of the Soyuz U and Soyuz FG launch vehicles are realized, the long term affect on the ISS operation will be relatively minor. The last few Space Shuttle flights, and especially STS-135 were able to deliver consumables, spares, utilization hardware and samples to provide margin through CY 2012. The bigger concern at this time is the ability to return to a full complement of 6 crewpersons onboard the ISS as soon as possible to maximize utilization for the United States. The Soyuz FG booster used to launch the Soyuz TMA crew vehicles is a variant of the Soyuz U which experienced the failure, and its launch resumption will be dependent on the successful Soyuz U launch of Progress 45P on October 30th. If that launch is successful – and I have every confidence it will be - the next crew will be launched to the ISS on or about the 13th of November and the ISS will return to 6 person crew on 26 December, 2011.

With regard to the adequacy of the Russian return to flight effort, I have not received briefings on the activity or results of the Russian Investigation Commission regarding the recent (24 August 2011) failure of the Soyuz U carrying the Progress M-13M/45P logistics vehicle. However, Mr. Gerstenmaier recently received these briefings from the Russian experts in Moscow and I feel the best use of our time today would be for me to yield the response of this question to him. I would like to comment on the reliability history of the RD-0110 engines used on the Soyuz launch vehicles. Out of a block of 6 engines, five are flown and one is test run for the full nominal 3rd stage burn duration of 240 seconds, and then inspected. Prior to this first failure, there have been a total of 1,800 RD-0110 engines that have flown, and an additional 360 that have undergone the 240 second test run. This equates to a total of 2,160 RD-0110 engines that have been successfully operated. Although not directly involved in this investigation, I would like to share a perspective. In 1999 I was asked by the Administrators of NASA and Roscosmos to engage in a full understanding of the Proton launch failure investigation. Specifically, to have the Joint US-Russian Commission, which I co-chair, review the completed Russian investigation on the causes for the Proton booster rocket failures in 1999. This included the corrective action to be taken, and the safety, reliability, and quality assurance processes which were to be implemented for the Service Module (1R) launch vehicle. The trust and respect we had developed through our years of Joint Commission work resulted in very thorough, open and comprehensive briefings on the failure of the Russian Proton launch vehicle, in the investigation process, in the corrective actions taken to preclude a repeat of the failure, and of the extensive retesting of hardware to be used for flight.

With nearly 40 years of continuous and close working relationship with the Russians and their space program, I can attest to their thorough and complete approach to problem solving, and to their robust manufacturing and test program philosophy.

As for the impact to the US associated with the Soyuz launch vehicle not being able to return to flight, I would submit that today, there is no other vehicle in the world capable of delivering crews to the ISS other than the Soyuz TMA crew spacecraft.

In response to your question regarding contingency plans, the answer is yes, and in fact NASA is already exercising the first steps of the contingency plan. This plan was refined and formalized as a result of the Columbia accident investigation so the ISS program is well versed in dealing with this type of contingency. The ISS can be maintained in orbit without a crew for a time. The critical systems for ensuring safe operation of the ISS are all able to be controlled from the ground and designed with robust redundancy should an anomaly occur. It is my opinion that at this time adequate contingency plans are in place to ensure the continued safe operation of the ISS.

Mr. Chairman, in addition to the comments I have just given, I would like to submit for the record, as Attachment A, a summary of the Commercial Resupply Services

review recently conducted by the ISS Advisory Committee and the Aerospace Safety Advisory Panel. This review was Co-Chaired by Vice Admiral Dyer and myself at the request of the Associate Administrator for Space Flight Operations Mission Directorate, to review the status of the two Commercial Resupply Services (CRS) contractors for the ISS – Orbital Sciences Corporation (Orbital) and Space Exploration Technologies Corporation (SpaceX). The focus of this meeting was the status of the SpaceX "Dragon" and the Orbital "Cygnus" logistics vehicles.

Mr. Chairman, I thank you and the committee for giving me this opportunity, and thank you for all you do to advance American human space flight.

Appendix A
Summary of Findings
ISS AC-ASAP Review of
SpaceX "Dragon" and Orbital "Cygnus" Logistic Vehicles
9 August 2011, NASA-JSC

On August 9, 2011, at the request of the Associate Administrator for Space Flight Operations Mission Directorate, members from the NASA ISS AC and the ASAP met jointly in a fact-finding session at the NASA Johnson Space Center (JSC), Houston, Texas, to review the status of the two Commercial Resupply Services (CRS) contractors for the ISS – Orbital Sciences Corporation (Orbital) and Space Exploration Technologies Corporation (SpaceX) The focus of the working groups from the ISS AC and the ASAP (hereinafter referred to as the "Review Team") was to review the status of the SpaceX "Dragon" and the Orbital "Cygnus" logistics vehicles. The Team's review was limited to only one day, and therefore should not be considered thorough or complete.

Both SpaceX and Orbital launch schedules (respectively, November 2011 and February 2012) are very success oriented, but as a result of prepositioned spares and consumables, NASA is in a position to absorb up to a year's delay in either or both logistics delivery schedules. The Review Team strongly supports the ISS Program Office (ISSPO) plans to keep contingency options in place in the event of extended CRS delays. With current manifest planning, six-crew operations aboard the ISS cannot be logistically sustained beyond January 2013 without CRS.

A number of items attracted concern and comments from the review team:

SpaceX Aggressive mission planning: Combining the SpaceX C2/C3 mission with two Orbcom launches appears to be very aggressive mission planning. At the time of this review, the ISSPO had not approved this mission, and was carefully considering all aspects. In SpaceX's presentation, one of the comments that SpaceX repeatedly made was the need to "keep it simple" for mission success; however, by introducing the additional payload launch, complexity would be added. At the time of this review, NASA had not had time to review this proposal. If the decision is to allow this additional launch requirement, it seems to the Review Team that it is added complexity and has the potential to compromise focus on the demonstration.

The SpaceX development and test schedule seems highly compressed. To go from System Readiness Review (SRR) to first flight in three months—with most of the systems engineering reviews taking place in one month—is not consistent with good practice and experience. As a general observation, both groups did address their respective safety efforts. While the time allotted in the discussions was not sufficient for the group to unequivocally endorse the safety efforts, the Review Team did not find any indications of significant systemic failings of their safety efforts.

Safety and Mission Success: During discussions with ISSPO representatives, The comment that "NASA was responsible for Safety, and Mission Success was the responsibility of the Contractors", raised concern with some of the Review Team members. Realizing different guidelines and responsibilities exist for the COTS Space Act Agreement, the Review Team has concern about the perceived responsibility in the event of a catastrophic failure. The ISSPO acknowledges this concern and is exercising insight and oversight to the extent possible under the Space Act Agreement and the Contract to make sure that it is well defined and covered. Regarding the question of allocation of responsibility for mission success for the early flights, it is very likely that NASA cannot escape being seen (at least partially) as responsible for mission success. This is a concern, and while it cannot likely be easily settled, it seemed somewhat casual in the current discussion. Written ground-rules and assumptions need to be well documented. NASA needs to ensure there is a clear, well laid out understanding of the responsibilities.

Different Approaches: There is a major difference in the design and verification approaches being taken by SpaceX and Orbital. SpaceX builds their computers up in house using commercial grade parts while Orbital purchases a computer using mil-spec, radiation-hardened parts. SpaceX has a one-size large thruster that is used for all operations (fine maneuvering is accomplished by millisecond pulsing of this large thruster), while Orbital has a more traditional approach with a large thruster for spacecraft transfer and small (7lb.) thrusters for fine maneuvering. SpaceX builds the majority of their components in house while Orbital procures a large number of their components from second sources. Both approaches, while different, can be made to work with a performance-based contract.

Flight Rules; There was concern voiced that there was no formal document signed by all parties that defines who has go-no go authority during all phases of flight. While the Review Team was sure that those discussions have taken place, this should be formally documented, with clarity of language that all parties have agreed to and signed. There was Review Team consensus on this issue.

Software; During the Orbital presentation, one issue that was brought up was the frequency response of one of the contractors. While the explanation was good, the 2 Hz cycle being used leaves open the question about latency in the Operational Flight Program (OFP) resulting in a "PIO" situation. The SpaceX Software presentation was unsettling to the Review Team. There was no Capability Maturity Model Integration (CMMI) accredited capability or process, and the software chief said he didn't worry about errors because "there were no mistakes in the software." In the Review Team's experience, this is unlikely. Another comment was "we don't set requirements, we just do coding." The very essential part of software development is understanding that of requirements so as to identify missed requirements, unexplained actions, and possible unsafe conditions.

Crew Hazards; NASA systems personnel working with the two companies reassured the board that proper flight rules and hazard mitigation would be in place to include crew

precautions for use of eye protection and proper use of telephoto lenses to prevent exposure to LASER and other radiation hazards. Off-gassing requirements are similar to those of other vehicles such as the Multi-Purpose Logistics Module (MPLM), the Automated Transfer Vehicle (ATV), and the H-II Transfer Vehicle (HTV).

MMOD Shielding: The MMOD requirements and environmental models for commercial resupply vehicles were developed several years ago to provide consistent MMOD protection for all ISS resupply vehicles (ATV, HTV, SpaceX Dragon, and Orbital Cygnus). Damage to the Thermal Protection System (TPS) of SpaceX Dragon that causes loss of vehicle during entry or damage causing vehicle functional failure of either the SpaceX Dragon or Orbital Cygnus vehicle is not included.

Engine Failures and Anomalies: Although not the focus of this review, propulsion is critical to meeting the launch schedules. In the case of Orbital, there was a detailed discussion on the failure and the corrective actions. In case of SpaceX's early engine shut down, the Team didn't see that kind of detailed discussion. Only in response to a direct question (and after the SpaceX presentation was completed) was there acknowledgement that "We had an engine shut down early on the previous launch, but that's OK." There was no explanation or root cause analysis or corrective action on this particular anomaly. This statement is troubling, i.e., not recognizing that premature engine shut down is a significant event. Orbital uses a rocket engine that is from the old Russian N1 rocket. It has experienced a recent firing failure at Stennis due to build up of stress fractures, and it has not had normal non destructive inspection (NDI) or testing (it is now undergoing inspection and testing).

Culture Observations: Experience has shown that an organization's culture can and does affect the decision-making processes and the level of risk the firm is ready to assume. A number of positives were noted during the briefings. Identified differences in cultures can be a benefit, if the differences are recognized and used in a positive manner. SpaceX and NASA are aware that their cultures are vastly different. Orbital and NASA are aware that their cultures are somewhat different from each other.

There appears to be good communication between all three organizations on technical detail. NASA has been studying, measuring, and working on opening up its culture and has made progress. SpaceX has an entrepreneurial mindset which is emphasized and encouraged throughout the entire design team. While this is a proven success process in many business fields, given the complexities of building and operating spacecraft there is a concern that too much streamlining of accepted "best practices" without an associated experience base could lead to unexpected challenges to mission success. SpaceX has addressed this issue by ensuring that some key personnel with NASA backgrounds are in place and charged with monitoring this tendency. There are several items of concern with respect to safety culture. Both commercial cargo providers could pay more attention to the cultural differences in a more formal manner. NASA Commercial Cargo personnel who interface with the contractors/partners have an excellent opportunity to be alert to cultural issues that could harm the outcomes that all parties seek, and it is not clear that they are effectively trained to recognize their role

and to execute against it. Unfortunately, the language contained in the Space Act Agreements is so obscure as to what is and is not allowed, it has blurred NASA's current oversight role. It will be beneficial to the program for executives of all three organizations to continue to recognize their roles in establishing a good "tone at the top."

General Observations; The importance of NASA as the keeper of the broad body of knowledge on space flight, and the importance of their role in shepherding commercial space forward cannot be overemphasized. This is working well, but the review team strongly encouraged aggressive transparency between the companies and NASA Headquarters and NASA centers with regard to the issues and the challenges, calling upon that body of knowledge to move forward. Also, there is the importance of transparency internal to NASA.

With regard to Orbital and SpaceX, Orbital generates the confidence of a company that has "been there, done that." They understand best practices. They also have the humility borne of experience; they understand how hard this is. SpaceX is entrepreneurial; their thinking is a fresh approach. They challenge conventional wisdom and have the potential to deliver at lower cost with innovations; they are aggressive by nature. However, their comments with regard to software were very disturbing and presented a lack of insight and sophistication on what can go wrong in this business. Schedule compression is also a concern.