NASA AEROSPACE SAFETY ADVISORY PANEL
National Aeronautics and Space Administration
Washington, DC 20546
Dr. Patricia Sanders, Chair

March 7, 2017

Mr. Robert M. Lightfoot, Jr.
Acting Administrator
National Aeronautics and Space Administration
Washington, DC 20546

Dear Mr. Lightfoot:

The Aerospace Safety Advisory Panel (ASAP) held its 2017 First Quarterly Meeting at Kennedy Space Center, Florida, on February 22-23, 2017. We greatly appreciate the participation and support that was received from the subject matter experts and support staff.

The Panel submits the enclosed Minutes and Recommendation resulting from the public meeting for your consideration.

Sincerely,

Patricia Sanders

Patricia Sanders
Chair

Enclosure

ASAP AEROSPACE SAFETY ADVISORY PANEL
Public Meeting
February 23, 2017
Kennedy Space Center, Florida

2017 First Quarterly Meeting Report

Aerospace Safety Advisory Panel (ASAP) Attendees
Dr. Patricia Sanders, Chair
CAPT (Ret.) Christopher Saindon
Mr. John Frost
Dr. Donald McErlean
Dr. James Bagian
Lt Gen (Ret) Susan Helms

ASAP Staff and Support Personnel Attendees
Ms. Carol Hamilton, NASA ASAP Executive Director
Ms. Marla King, NASA NAC Administrative Officer
Ms. Paula Burnett Frankel, Writer/Editor

Telecon Attendees: 43 participants

NASA Attendees:
Michael Haddad
Zach Hand
Derrick Bailey
Robert Schwader
William L. Hall
Kevin Villa
Derrick Matthews
Joe Olivo
Jeffrey Hibshman
Ronald Driggers

Other Attendees:
Ken Bowersox, NASA Advisory Council
Michel Lacerda, Georgia Tech
James Dean, *Florida Today*
John Ilgeufritz, SMASS

Opening Remarks
Ms. Carol Hamilton, ASAP Executive Director, called meeting to order at 2:15 p.m. EST. She indicated that there had been no comments or questions submitted prior to the meeting, but there would be time at the end for public comments or questions.

On behalf of the Panel, Dr. Patricia Sanders, ASAP Chair, thanked Mr. Robert Cabana, Kennedy Space Center (KSC) Director, and his people at the Center for their hospitality and support in hosting the Panel's first quarterly meeting of 2017. She offered the Panel's acknowledgement and praise for the remarkable progress made at KSC. When the last Shuttle launched from Pad 39A, the future was not looking very bright. However, today, KSC has become a vibrant spaceport and a key component of future space exploration.

Dr. Sanders noted that after her remarks, members of the ASAP would discuss the status of the various elements of NASA's program of record on which they focused this week's fact-finding sessions. It is truly a dynamic time as several programs evolve from paper design to actual hardware and testing, with flight tests on the horizon.

Dr. Sanders addressed one item that was discussed with NASA leadership—the recently initiated feasibility study for flying crew on the first Exploration Mission (EM-1) of the Orion/Space Launch System (SLS). She indicated that the Panel has confidence in the approach that NASA is taking to this assessment, and they had excellent dialogue on the topic at the fact-finding session. However, the ASAP is compelled to provide a note of advice and caution as NASA examines the risk associated with a potential alteration to the already fairly aggressive test

program of record. The baseline plan is mature with substantive and critical objectives for the planned, uncrewed EM-1 designed to manage risk for the subsequent crewed EM-2—for example, a flight test of the heat shield. Also, the current vehicle planned for EM-1 was not designed for human rating, would not have a full Environment Control and Life Support System (ECLSS), nor would it have the software and other aspects necessary for crewed operation. Several changes to the baseline program would be required, adding complexity, unknowns, and almost certainly, risk, not to mention the cost, schedule, and potential opportunity cost implications. Dr. Sanders emphasized that the Panel was not proposing what the outcome of NASA's assessment should be; however, it strongly advised that NASA carefully and cautiously weigh the value proposition for flying crew on EM-1. NASA should provide a compelling rationale in terms of benefits gained in return for accepting additional risk and fully and transparently acknowledge the trade-offs being made before deviating from a mature approach to certification of the Orion/SLS vehicle for human space flight. If the benefits warrant assumption of additional risk, the ASAP expects NASA to clearly and openly articulate its decision process and rationale.

Launch Complex 39 Readiness for Commercial Launches

CAPT Chris Saindon reported on the Panel's review of the status of Pad 39A as presented by Mr. Cabana and Mr. Robert Holl, KSC's Technical Operations Integration Manager. The discussions focused on the multiuser spaceport and improvements done at KSC over the past few years. Specifically, Mr. Cabana described the upgrades to the Vehicle Assembly Building (VAB), with platforms constructed to support SLS. There has been considerable progress. The Mobile Launcher work appears to be going well, as does the Crawler Transporter refit and refurbishment. Most the focus of Mr. Cabana's and Mr. Holl's briefing was on operations at Pads 39A and B and support of commercial spaceflight activities, specifically with SpaceX, Orbital ATK, and Boeing. The ASAP does not have any major concerns with the way commercial launches are being done at KSC.

Mr. Holl outlined the Director's responsibilities overall—to ensure an environment where users can safely and effectively execute their operations. Critical components of that are to ensure support for commercial landing and recovery as well as to ensure that risks to personnel and KSC critical infrastructure and assets are acceptable. The FAA has the responsibility to regulate and license all of the commercial launches at KSC—primarily, it focuses on public safety outside the fence line. The ASAP is satisfied with the process that has been put in place at the Center, and there are no major concerns with it. There was some discussion regarding the interaction with the 45th Space Wing for autonomous launch termination. To launch commercially here, autonomous launch termination is critical. Some of the commercial operations outside the KSC fence line (at Canaveral Air Force Station, Pad 41, for example), such as the Atlas rocket, do not have autonomous termination. The role of KSC will be different in that type of environment—the 45th Space Wing will maintain authority over launch termination. CAPT Saindon noted that something the Panel found interesting was that decision authority is held by the commercial provider (SpaceX, for example, on the one launched a few days ago). The readiness review portion that the KSC Director does pertains to infrastructure and support readiness. Overall, the goal is to leverage requirements that exist at the lower level, such as the FAA requirements for the licensing of the system for space flight, and not duplicate requirements at KSC at the program level. The certification "safe-for-flight" for the system on a commercial launch rests with the commercial provider. Overall, the ASAP is happy with the progress on how services are provided at KSC.

Asset Protection

Lt. Gen Susan Helms addressed the ASAP's fact-finding session with Mr. James Leatherwood, Principal Advisor on NASA's Enterprise Protection Program (EPP). To provide context on the issue, she read the first paragraph on this topic from the ASAP's 2016 Annual Report:

Throughout 2016, the ASAP has had the opportunity to explore and review the asset protection strategies at several NASA Centers, culminating in an Enterprise Protection Program review at the ASAP's 4th Quarterly Meeting at Johnson Space Center [October 2016]. *NASA leadership has clearly recognized that cyber security for both institutional networks and mission systems has been a growing concern and needs additional management structure and resources. To NASA's credit, there has been action on this issue, once discussions between NASA senior leadership and ASAP members began.*

This was where the ASAP was at the release of its Annual Report in January 2017. Since then, NASA's Office of Inspector General (OIG) has released an audit on Critical Infrastructure Security, report IG 17-11 dated February 8, 2017, which matches the same concerns. Lt. Gen. Helms read a couple of key parts from the initial paragraphs of the audit report:

Despite its significant presence across the Agency and its criticality to the success of the Agency's multi-faceted mission, NASA has not adequately defined Operational Technology (OT), developed a centralized inventory of OT systems, or established a standard protocol to protect systems that contain OT components.... NASA also lacks an integrated approach to managing risk associated with its critical infrastructure that incorporates physical and cyber security considerations in all phases of risk assessment and remediation. Specifically, the security of physical and cyber components of NASA's critical assets is managed with minimal collaboration among key Agency stakeholders and does not involve the Office of Strategic Infrastructure, which manages the supporting infrastructure associated with critical assets. This disjointed approach has led to duplication of effort and gaps in security planning and risk remediation at both the Agency and Center levels.

Lt. Gen Helms stated that her reason for reading these paragraphs was to point out that the ASAP noticed a need for improvement in this area (protecting mission systems and operational security), NASA did its own study of the problem, and the NASA OIG produced the audit report. At the meeting with Mr. Leatherwood, NASA's holistic approach to address the issue was discussed. He identified the pertinent recommendations from the OIG report:

1) Develop a framework to coordinate security efforts across the Agency.
2) Develop a standardized process to assess Agency cyber and physical assets for NASA critical infrastructure.
3) Ensure appropriate Agency personnel are included during functional reviews and assessments.
4) Coordinate the development of a methodology for the identification and protection of interdependencies.
5) Develop security policy and procedures for managing the protection of OT.
6) Establish an integrated oversight body.

In the ASAP's view, these recommendations from the OIG audit report are synergistic with some of the things that would make sense to bolster the security for mission systems and operational infrastructure. Of these six recommendations, only one has been completed to date: the establishment of an innovative oversight body, called the Enterprise Protection Board (EPB). They are also working to establish a lower level Industrial Control System Working Group, which would feed the EPB with recommendations on policies, procedures, and strategies for the issue of infrastructure and cyber security. In its response to the audit report, NASA has also given itself a timeline to address the other five IG recommendations: October 1, 2018.

There are already several things underway, and some partnerships are developing between NASA and other government agencies to help baseline an institutional assessment and a cyber assessment. In addition, NASA has initiated the development of enterprise protection management and policy. They have also initiated the development of a probable budget submittal for the 2019 budget for additional resources to support enterprise

protection. They have initiated a baseline of best practices, some of which already exist within NASA. The ASAP's 2016 Annual Report noted that the Human Exploration and Operations Management Directorate (HEOMD) has already done a lot of positive things regarding this issue. The EPP is looking at HEOMD's best practices to export across the broader scope and scale of NASA's mission programs. It is worth mentioning that they are maturing an awareness of program managers and technical authorities on the problems of enterprise protection so that the program managers and technical authorities can work today to start improving the security of mission systems in the trade space that is within their control. Lt. Gen Helms noted the ASAP recommendation from its last meeting in October 2016:

> *NASA should make it a matter of policy that priority is given to obtaining the appropriate level of security clearance for all personnel essential to implementing the Enterprise Protection Program, including the appropriate program managers.*

A first step in implementing improved enterprise protection is to get the witting knowledge of what one is protecting against from a threat standpoint. The previous day, the ASAP received a briefing from NASA on the status of their plans related to getting security clearances. Some of the actions they have already begun are: identifying the people who need clearances, documenting the requirement for clearance in the appropriate position descriptions, tapping personnel to submit paperwork for clearances, and working the timeliness and numbers with the clearance-granting agencies to have those clearances occur. Getting the clearances has presented an administrative surge as well as a culture-change challenge. Many of the employees who now have this as a requirement for their positions and performance have not had clearances in the past. NASA is deliberatively working through the problem of both managing the workload mechanically as well managing the culture change. From what was learned yesterday, the ASAP was satisfied that NASA recognizes the need to do so. Measurement of progress will be shared with ASAP in the near future. According to NASA, what that means is that they will let the Panel know how many NASA employees have been identified as needing security clearances, how many have submitted the paperwork, how many have successfully gained their clearances, etc. This report will provide a good sense of progress in addressing the ASAP recommendation at upcoming meetings.

Overall, there has been some good progress in last couple of months. The Panel has been very pleased with NASA's approach to enterprise protection. The OIG report added another layer on top of that regarding detail on the kinds of things they need to address for overarching security and infrastructure security. The ASAP has noted that if NASA intends to meet its own plan by October 1, 2018, and to make judicious progress in implementing the security of mission systems, the Agency appears to have tasked itself with considerable amount of work without an adequate amount of resources. The ASAP will continue to monitor progress in this area, including appropriate resources.

Commercial Crew Program (CCP)

Mr. John Frost noted that the CCP is a key element of NASA. The ASAP had an excellent discussion with Ms. Kathy Lueders, Commercial Crew Program Manager, who continues to do a great job. The team is continuing to make progress. Ms. Lueders reviewed multiple milestones; in summary, metal is being cut, tests are being run, and they are moving quickly towards having flight vehicles. The ASAP looked briefly at the Sierra Nevada Corporation activity under a Space Act Agreement, which is also making progress. The ASAP reviewed the risks that the Program is tracking. Currently, they have a red 3x5 (three probability, 5 severity) risk on the ability to close on the Loss Of Crew number. The current design does not quite meet it, and the Program is looking at design changes and other actions to buy down the risk. Another risk of low probability but high severity is an abort to a heavy sea state.

The first two post-test missions for each of the providers had been previously committed by NASA. Both providers are investing huge amounts of research and development funds, and two flights is not enough to recover that. The good news for the providers is that in December 2016, NASA committed for flights three through six, although "authority to proceed" has not been granted and will depend on progress. The first uncrewed demo flight for Boeing will be June 2018, and the first uncrewed demo flight for SpaceX is planned for November 2017. The ASAP took a detailed look at the hazard analysis process—how it is working on the provider side and how the review process is working on the government side. In both cases, there was a slow start, but progress is being made.

The ASAP looked carefully at the Boeing first crewed demo flight in August 2018. Many important milestones have been accomplished. Boeing had a successful parachute drop yesterday morning and has more coming up. The Boeing team just completed Critical Design Review (CDR) on their ascent and entry suit. One of the top Boeing risks is the RD-180 engine certification. The engine has a long history, but it has been difficult to get detailed design information for certification. The Boeing team is developing an approach that takes advantage of the long history of successful use, combined with information that they can obtain. During the fact-finding session, there was a good discussion of heat shield testing. The Boeing team is working on improving the heat shield performance. The ASAP also reviewed the zero fault tolerant SureSep separation ring, which has been an issue from the beginning. Boeing is making progress on getting comfortable with having a single point failure component that has a great deal of reliability built into it.

On the SpaceX side, the team is making good progress on parachutes and the environmental system as well as elimination of variances. There was a good discussion on cracked turbine blades—a potentially catastrophic failure. NASA has extensive expertise regarding turbine blades and is bringing its experts' knowledge to bear. It appears that a redesign to fix the problem is technically feasible. With the redesign, it is essentially a new engine and will require certification. The SpaceX team is now working on their Block 5 upgrade. Everyone has been concerned about a continually changing configuration. The Program has reached an agreement with SpaceX that there will be seven flights on a "frozen" configuration of Block 5 before the first crewed flight occurs. The ASAP also reviewed the "load and go" concept and looked at the recent SpaceX failure investigation. It appears that the proximate cause has been found, but there are some loose ends and more work on corrective actions needs to be done. However, there has been a great deal of progress on a very difficult mishap investigation.

Mr. Frost noted that a common theme in the recent two commercial cargo mishaps can be traced to the systems engineering and integration (SE&I) process and the controls involving design, analysis, manufacturing, quality control, qualification, and operations, including operational test. It is important that a rigorous and disciplined SE&I process be in place, and it must be shown to be effective over time. This must form the underlying foundation on which all other certification is based. In other words, the Panel feels that it is critically important to understand how the system is "breathing and talking" to itself and how components are affecting each other. Mr. Frost stated that the ASAP is making the following recommendation to NASA:

> **The Panel recommends that NASA require the Commercial Crew providers to produce verifiable evidence of the practice of rigorous, disciplined, and sustained System Engineering and Integration (SE&I) principles in support of the NASA certification and operation of commercial crew transportation services to the ISS.**

This is a basic concept for any rocket construction. It sounds straightforward, but the hard part of this will be figuring out exactly what it means and what it looks like at each provider, because there are slightly different ways of doing it. It will not be an easy job, but the ASAP feels that it is an important one. Dr. Sanders agreed, and

noted that the precision with which one defines SE&I is imprecise. Verifying that such a process is in place is not necessarily easy. She indicated that the ASAP will work with NASA in defining how they might go about meeting this recommendation.

Exploration Systems Development (ESD)

Dr. Donald McErlean reported on the fact-finding sessions with Mr. Bill Hill, Deputy Associate Administrator, ESD; Mr. John Honeycutt, SLS Program Manager; Mr. Mark Kirasich, Orion Program Manager; and Mr. Mike Bolger, Ground Systems Development and Operations (GSDO) Program Manager.

Dr. McErlean noted that the SLS rocket is considerably larger than any of the current launch vehicles that we have today. It has about four times the lifting capability of the commercial rockets currently in use. This is the system that will ultimately take us beyond low Earth Orbit (LEO), beyond the Moon, to Mars and perhaps beyond. It is a core program to NASA. The SLS is being accomplished in a number of Centers, but KSC and JSC are the leads. It was unfortunate that a tornado hit the Michoud Assembly Facility (MAF) on February 7, 2017. Luckily, there were no serious personnel injuries, but there was some significant damage to the facility itself. Some of the most critical facilities, e.g., the huge friction-stir welding facility, which, if damaged, could have set the program back a year or more, was fortunately spared. However, NASA estimates that the damage will cost a couple of months on the schedule. The people at MAF are working hard to put things back together.

With Mr. Honeycutt and his team, the ASAP went through a review on various components of the SLS system. The SLS team is putting together the tanks, the intertank stages, and the outer shell of the core rocket. The large pieces are beginning to undergo structural test qualification. They have started the weld qualification pieces and are taking them through both non-destructive inspection (NDI) and destructive evaluation. MAF is the world leader in the pursuit of the friction stir weld process for pieces of this size and thickness. They have kicked off the Design Certification Review for various pieces. The engine section qualification has been completed, the liquid hydrogen tank has been completed, and the flight unit has been welded. Dr. McErlean described the typical process: a qualification unit is made first; then it is destructively taken apart, pieces taken to the laboratory, the welds checked, etc.; then the flight unit is produced by same process if the qualification unit passes inspection. The SLS team is continuing to work through a considerable amount of structural qualification. With regard to the boosters, they had begun to pour the booster segments and found an anomaly with the interaction between the propellant and the layer that is put between the propellant and the liner to allow a certain amount of motion. It was discovered that under certain heat conditions, there can be some outgassing of this layer that can cause some voids in the propulsion. It is not 100 percent clear that these are disqualifying, and the team is undertaking an analysis and an investigation to determine if the segments could still be used for flight. Even if the segments are rejected, NASA already has a fix for the problem that has been put in place. They are progressing with the boosters for both EM-1 and EM-2. There will be no delay in EM-1 due to this issue. Worst case, they can pull forward some boosters cast for EM-2, use them for EM-1, and use the extra time to cast additional ones for EM-2. It is a good news story from a schedule perspective. With regard to the engines, the first 14 are legacy engines—Space Shuttle Main Engines (SSMEs)—and they are undergoing CDR for use on the SLS. Dr. McErlean noted that one of the things that was most interesting was that in the 20 years since the design of the original SSMEs, industrial processes and technologies have improved significantly. NASA has instituted a rigorous program to look at the design of the engine, and for future engines, determine if they can be produced—using improved industrial processes and newer technology—to be more reliable and/or for less cost. Some of the results are amazing. The team has found ways to take about 30 percent of the production cost out of these engines. Also, they have eliminated about 700 independent welds using other processes and have eliminated about 700 individual parts. The future legacy engines will be cheaper as well as more reliable. The SLS Program is moving ahead with the new, modern-technology engine controller units, and the first one was delivered for qualification testing earlier this month.

Orion, which includes the European Space Agency Service Module (ESM), has moved schedule. Originally, it was designed to be in place last month, then slipped to summer, and has now slipped to fall. The ESM is a driving element on the critical path. However, CDR has been completed satisfactorily, and construction, manufacturing, and testing of the first ESM for EM-1 is underway. The ESM for EM-2 has been initiated. Several reliability and safety improvements that were recommended for the ESM are being incorporated, and they will be implemented at various places. Of the 13 different safety improvements, 9 will be in the first ESM and the other 4 will be in the second ESM.

There has been considerable progress on the ECLSS, which has been a particular concern of the ASAP. The ECLSS as it stands today will be partially flown on EM-1. As Dr. Sanders mentioned earlier, there will be a feasibility study that looks at putting crew on EM-1. One of the changes that would have to be made to the schedule would be to pull forward the remainder of the ECLSS, which is a necessity for crewed flight. Parts of the ECLSS are already under test on the International Space Station (ISS). For example, the crew system for SLS/Orion uses an amine swing bed for removal of carbon dioxide and humidity. This system is slightly different and more efficient and compact than the system currently being used operationally on the ISS. The amine swing bed has already run over 2000 hours in testing and will continue to run in test on ISS over the next several years. The suit development for the ECLSS crew continues and is working very well. ISS risk reduction is ongoing, and wherever possible, elements are being tested on ISS.

The heat shield is a critical component. On Exploration Flight Test (EFT)-1, the original heat shield was a monolithic pour of the heat shield material. After ETF-1 flight, cracks were found in the heat shield. They may or may not have been potentially catastrophic failures, but engineering did not feel that this configuration was adequate. The Program has gone to a block-type configuration for the heat shield. The obvious question regarding the block configuration is how to verify the bond between the blocks and the bond of the blocks to the metallic surface of the crew capsule. The team has been working on this problem over the past couple of years, and the verification demonstration is well underway. They have addressed the problem in two principal ways: (1) a well-defined and robust technical process for bonding, and (2) non-destructive evaluation (NDE). Previously, the NDE technology that was available could not look down through the blocks; it could only look up through the metal, and, from this view, stringers and supports obscured a significant portion of the capsule. Since then, two new NDI techniques have been developed: ultrasonic and a high-frequency sensor that can look down at the bond line completely from the outside. These new techniques will allow an excellent assessment of bond quality.

The Program has several “watch” items, including the ground system. The VAB has now been almost completely refurbished. The moveable platforms have been altered to match the outer mold line of the SLS for the EM-1 configuration with the Interim Cryogenic Propulsion System. When the Exploration Upper Stage is put in place, the platforms must be extended, because the Block 1B configuration is 40 feet taller. The Mobile Launcher has been almost completely redesigned and rebuilt and is nearly complete. The Crawler Transporter is complete and ready to go. They are in the final testing phase on the umbilicals that connect the rocket with the internal support equipment that resides in the tower. The Launch Control Complex has undergone a refurbishment and is now ready to support SLS launches. The progress has been at a great pace, and the ASAP is looking forward to the 2018 launch of EM-1 and return to deep space exploration. Currently, the top program risks include some schedule concerns (e.g., the repairs at MAF), the challenging installation schedule for the new equipment, software (always a potential schedule risk), the potential recasting of boosters, and the ESM, which now appears to be stabilized and should soon be delivered to KSC. The Center will soon be in the midst of a huge assembly job for what Dr. McErlean called “one big hummer” of a rocket.

International Space Station

Dr. James Bagian reported on the ASAP's interaction with the ISS Program. From the briefing from Mr. Kirk Shireman, ISS Program Manager, the Panel continues to see a well-organized, well-planned, well-executed Program. Even unanticipated problems are dealt with in a very expeditious and professional manner. Today, SpaceX's Dragon capsule successfully docked at the Station after a one-day delay. Other good news includes a successful negotiation with the Russians to gain some additional seats for crew to the ISS through the end of CY 2019. This will ensure accessibility of crew to ISS and take some schedule pressure off the CCP. While the CCP should proceed with all due haste, the Panel does not want to see unnecessary schedule pressure that could compromise safety. Also, Mr. Shireman explained that starting in April, the Russians will reduce from three to two crew members on a continuing basis, which will allow four U.S. Operating Segment (USOS) members later in the year. Station utilization continues to be around 43 hours per week for investigations. The consumables are fine, and the USOS has been able to help the Russians with their consumables when they had some issues with Progress resupply. One of the other new technologies is the robotic external leak locator to track down an area of suspected ammonia leak and how it might be remediated. This leak is not a major leak or threat, but they want to know more about it. In terms of efficiency, they are hoping to have a triple extravehicular activity in the next increment.

Mr. Shireman discussed some of the concerns that they see and things that can affect the Station. The Indian Space Research Organization (ISRO) launch of 104 satellites on a single rocket earlier this year is an example of an increasing problem. This brings up the issue of everything from small CubeSats to larger satellites placed in LEO. They can orbit into the Station's altitude or produce a debris cloud that must be avoided. The Orbital Debris Program Office estimated that just from this one ISRO deployment alone, worst case, there could be an additional 1 to 1.5 percent chance of a required debris avoidance maneuver (DAM). This would be about 60 percent increase in the DAM plan. As more and more users put small satellites in orbit, the way in which they are controlled or not controlled can create future vulnerability, and this is a concern. At this time, the situation is not very well regulated. For domestic launches, the FCC has the responsibility for debris control on orbit. However, internationally, no governing body controls this situation. Also, there is the issue of detectability on orbit, either for what is launched or collision events that cause debris clouds. All of this presents an increasing risk that needs to be addressed. NASA is trying to proactively deal with this issue through voluntary cooperation of domestic industry and with internationals; hopefully, that will lead to something more than voluntary. The ASAP will continue to watch this issue with great interest.

Mr. Shireman also talked about the deorbit planning for the Station, either in a nominally planned or a contingency situation. This topic has been of interest to the ASAP since before 2012, and the Panel is still holding open a formal recommendation from 2012. NASA has continued to make progress and has assigned a NASA Project Manager for ISS deorbit planning activities. They have a draft recommendation for how this will be dealt with. The formal document is the "ISS Deorbit Strategy Document and Contingency Action Plan" (SSP 51066), which has been released for signature. Completion of review and signature is expected by March 2017. As they make progress, they have made it clear that the timeline is not as certain as they wish it would be. Some of the timeline is under NASA's control, but other parts require cooperation from the partners, particularly the Russians. The ASAP is still concerned with the timeline as progress is being made. One of the elements of the 2012 recommendation is that "NASA should develop a timeline for development of a controlled entry capability that can safely deorbit the ISS in the event of foreseeable anomalies." This part of the recommendation has not yet been satisfied, and it has been five years. NASA agreed that by the next quarterly meeting, they would present the forecast timeline to satisfy the requirements, as well as dependencies that stand in the way of things that may be out of their control, and what mitigation strategies could bring this to resolution. The ASAP is pleased to see progress, but more work is still needed.

Mr. Frost observed that deorbit could be a problem tomorrow, next week, or in ten years. It needs to be worked quickly. He suggested an action item to follow up on their commitment to the timeline. Dr. Sanders agreed that the ASAP would have an action item for the Program to report back at the next quarterly.

Lt. Gen. Helms made an additional comment on orbital debris. The U.S. Strategic Command, by national policy, has a mitigation role for orbital debris at the operational level. There are some discussions afoot about using a civilian agency, such as the FAA, to do that. Mr. Frost added that this problem is bigger than the ISS. Anyone who has assets in LEO is facing this issue, and many cannot maneuver to get out of the way.

Dr. Sanders noted that the Panel had experienced a very dynamic and productive couple of days. She opened floor to public comments or questions. There were none, and Dr. Sanders adjourned the meeting at 3:17 p.m.

2017-01-01 **Practice of System Engineering and Integration Principles by Commercial Crew Providers for Transportation Services to the ISS** [ASAP Point of Contact: John Frost]

Finding: The investigations into two recent mishaps on commercial launch vehicles have concluded that the mishaps were unrelated because the immediate (or proximate) causes of the mishaps were different. However, in the opinion of the Panel, the underlying root causes of both mishaps can be traced to escapes in the System Engineering and Integration (SE&I) process and controls involving one or more of the following areas: design, analysis, manufacturing, quality control, qualification, and operations (including operational tests).

Recommendation: The Panel recommends that NASA require the Commercial Crew providers to produce verifiable evidence of the practice of rigorous, disciplined, and sustained SE&I principles in support of the NASA certification and operation of commercial crew transportation services to the ISS.

Rationale: Rigorous and disciplined SE&I processes and controls are essential elements of any engineering effort. When dealing with complex systems for human space travel, where inherent risks must be managed to an acceptable level, the emphasis on SE&I and cross-discipline engineering is even more critical. No amount of NASA oversight or insight into the performance of the commercial providers can compensate for a lack of rigor in the providers' SE&I processes and controls. On a regular basis, the commercial providers make numerous important decisions that do not rise to the level of NASA oversight. Their detailed knowledge of the system design, qualification, and performance generally exceeds that of the NASA engineers who provide insight and oversight. Thus, the responsibility for producing a system that provides an acceptable level of risk for NASA missions to ISS rests heavily on the commercial providers and their SE&I processes and controls.

Finally, it is important for the provider to not only furnish evidence that rigorous, disciplined, and sustainable SE&I processes and controls are in place, but they should also be shown to be effective over time. This is a foundation for all other certification activities.