Annual Report for 2016

Aerospace Safety Advisory Panel

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

January 11, 2017

The Honorable Charles F. Bolden, Jr.
Administrator
National Aeronautics and Space Administration
Washington, DC 20546

Dear Mr. Bolden:

Pursuant to Section 106(b) of the National Aeronautics and Space Administration Authorization Act 2005 (P.L. 109-155), the Aerospace Safety Advisory Panel (ASAP) is pleased to submit the ASAP Annual Report for 2016 to the U.S. Congress and to the Administrator of the National Aeronautics and Space Administration (NASA).

The Report, which was completed prior to enactment of the fiscal year 2017 budget, is based on the Panel's 2016 fact-finding and quarterly public meetings; insight visits and meetings; direct observations of NASA operations and decision making; discussions with NASA management, employees, and contractors; and the Panel members' past experiences.

NASA has made great progress over the past year in evolving a plan for deep space exploration, maturing the elements of the Exploration Systems Development programs, moving toward achieving a crew transportation capability, sustaining operations of the International Space Station, initiating the New Aviation Horizons, and focusing on enterprise protection. The Agency has the realization of several key milestones in its near future.

At this critical time, with designs maturing, hardware being produced, and testing intensifying, it is important to maintain a focus on safety, risk reduction, and mission assurance. Challenges and difficult decisions will need to be faced with clarity, transparency, and thoroughness. Inevitably, there will be risks that must be accepted, but that should occur only after thoughtful deliberation of alternatives, understanding the benefits of acceptance, and careful documentation of the decision including the process and rationale for arriving at it.

The ASAP reiterates the need for consistent program goals, funding, and schedules, also known as "constancy of purpose." Human space flight and exploration are inherently challenging and risky and require far-reaching, long-term national commitment to capitalize on painstakingly achieved knowledge and to realize the results of resource investments. The lack of consistent commitment negatively impacts cost, schedule, performance, workforce morale, process discipline, and—most importantly—safety.

The impact on NASA programs from continuing employment of Continuing Resolutions (CRs) is of concern to the ASAP. The uncertainty of an assured and exact budget for a long-duration, technically challenging program and the partial release of funds as the CR unfolds adds, at best, complexity to managing programs and, importantly to the ASAP, can distract from maintaining the required focus on safety.

The ASAP continued to benefit this year from open communications and transparency with NASA. NASA's senior leaders and staff members offered significant cooperation throughout the year and support to our assessments and the completion of the document. I submit the ASAP Annual Report for 2016 with respect and appreciation.

Sincerely,

Dr. Patricia Sanders
Chair, Aerospace Safety Advisory Panel

Enclosure

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

January 11, 2017

The Honorable Joseph R. Biden
President of the Senate
Washington, DC 20510

Dear Mr. President:

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

January 11, 2017

The Honorable Paul D. Ryan
Speaker of the House of Representatives
Washington, DC 20510

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Preface

The Aerospace Safety Advisory Panel (ASAP) was established by Congress in 1968 to provide advice and make recommendations to the NASA Administrator on safety matters. The Panel holds quarterly fact-finding and public meetings and makes “insight” visits to NASA Field Centers or other related sites. It reviews safety studies and operations plans and advises the NASA Administrator and Congress on hazards related to proposed or existing facilities and operations, safety standards and reporting, safety and mission assurance aspects regarding ongoing or proposed programs, and NASA management and culture issues related to safety. Although the Panel may perform other duties and tasks as requested by either the NASA Administrator or Congress, the ASAP members normally do not engage in specialized studies or detailed technical analyses. The ASAP charter is included as Attachment 1 on the enclosed CD.

This report highlights the issues and concerns that were identified or raised by the Panel during its activities over the past year. The Panel’s open recommendations are summarized in Appendix A, and the full text of the recommendation submitted to the Administrator during 2016 is included as Attachment 2 on the CD. The Panel’s issues, concerns, and recommendations are based upon the ASAP fact-finding and quarterly public meetings; insight visits and meetings; direct observations of NASA operations and decision making; discussions with NASA management, employees, and contractors; and the Panel members’ expertise.



I. Introduction

This year, the Aerospace Safety Advisory Panel (ASAP) continued to see NASA evolve its plan for space exploration beyond low-Earth orbit (LEO) with details of the path forward developing more completely over time. Positive progress continues in partnering with the commercial space industry through the Commercial Resupply Services Program, the Commercial Crew Program (CCP), and other cooperative efforts like the commercialization of an International Space Station (ISS) port. While true commercialization (i.e., driven by private sector demand as well as private sector providers) of LEO is not yet realized, these investments have the potential to eventually facilitate a reduction in the need for NASA's direct involvement and resource expenditure to access LEO and allow NASA to better concentrate on deep space exploration. Objectives for the testing to be accomplished in the cislunar Proving Ground are maturing as are the tools to perform those tests—Orion, the Space Launch System (SLS), and the associated Ground System Development and Operations (GSDO). The technologies that will be needed for deep space exploration are being identified—habitation, life support, robotic precursors, propulsion, and others—and have been initiated to develop the requisite tools, either independently or in cooperation with commercial or international partners.

While a great deal of work lies ahead and resources to adequately support it seem tenuous, the NASA approach appears to be one of balance between defining specific plans for implementation, retaining flexibility to take advantage of technologies as they emerge, and leveraging cooperative efforts as they develop. The complex systems under development, including their test objectives, have the capacity to further human exploration of deep space whether that takes humans to the vicinity of Mars, the surface of Mars, or another destination. Mission definition should continue to mature over time along with a commitment to a more specific path to exploration.

As the ASAP has noted before and reiterates particularly at this point in time, a far-reaching and long-term program such as space exploration requires a national commitment to "constancy of purpose." Human space flight is an inherently challenging and risky endeavor. The human space flight systems under development now—the Commercial Crew Transportation Systems and the Exploration Systems, consisting of Orion, the SLS, and the GSDO—are at a point where designs are maturing and hardware is being built, delivered, and tested. NASA is gaining the all-important knowledge for recognizing, understanding, mitigating, and, where reasonable and necessary, accepting risks. NASA is on the verge of achieving several major milestones in the next year or two:

- first flights of the commercial crew variants providing return to space flight of U.S. astronauts on U.S. vehicles,
- first Exploration Mission (EM) series test flight of the Orion and SLS,
- testing of key life support systems for exploration aboard the ISS, and
- launch and deployment of the James Webb Space Telescope.

Also, lest we forget that NASA has an important aeronautics mission, there will be the revitalization of that aspect of its portfolio with the New Aviation Horizons Initiative.

Constancy of purpose is critical, not only to realize the furtherance of the resource investments already made in these programs, but to capitalize on the painstakingly achieved understanding of their designs. An interruption in the development process brings a disruption to the knowledge acquisition necessary for addressing risk and achieving mission success. New starts mean beginning that process of understanding and knowledge gain over again, introducing not only additional expense, but also new risks that must be identified and dealt with. The ASAP continues to strongly caution that lack of consistent commitment negatively impacts cost, schedule, performance, workforce morale, process discipline, and—most importantly—safety.

A companion to constancy of purpose is consistent commitment to "doing the job right." NASA's program of work is challenging, and in striving to reach its goals, it is crucial to maintain the emphasis on safety and mission assurance and not allow schedule or resources to unduly erode that focus. On the path to achieving the upcoming milestones, unanticipated hazards will be discovered, leading to difficult decisions involving additional mitigation work, potential design changes, and risk acceptance. Tradeoffs between the alternatives, which weigh the potential benefits against the risks, will inevitably be made over time. Those tradeoffs and the resulting decisions must be transparent, thoughtful, thorough, well defined, and well documented.

Lastly, the ASAP is concerned with the pressure placed on the NASA program by the continued experience of continuing resolutions (CRs), especially year-long CRs. This budgetary practice, in lieu of the enactment of true appropriations, leads to inefficient use of resources as programs seek to cope with uncertain, less than appropriately sequenced, and often inadequate resource allocations across programs. The practice tends to cause short-term focus and endangers ongoing collaborations; but, of critical concern to the ASAP, it also may threaten safety and risk reduction as programs seek to make progress with ill-suited and inadequate funding profiles. The CR in effect at the time of this writing challenges Orion and the GSDO; places the EM-1 test flight at schedule risk; compromises the advanced exploration system development of necessary technologies for deep space exploration (e.g., habitation); stalls aeronautics initiatives; and could stress testing, risk reduction, and safety activities. The uncertainty with the exact budget and partial release of funds as the CR unfolds adds complexity to managing programs and executing long-lead acquisitions. This complexity and uncertainty can distract teams from maintaining the required focus on safety. Constancy of purpose, and indeed mission assurance, are heavily burdened by the use of CRs.

II. Calendar Year 2016 Activities and Overview

During 2016, the ASAP conducted quarterly meetings hosted by Kennedy Space Center, Marshall Space Flight Center, NASA Headquarters, and Johnson Space Center (JSC). ASAP members also made insight visits to Stennis Space Center, Michoud Assembly Facility, Armstrong Flight Research Center (AFRC), Goddard Space Flight Center, and Ellington Field, as well as insight visits to the commercial space facilities of Boeing, Space X, and a number of aerospace companies at the Mojave Air and Space Port. We held several focused reviews—daylong in-depth dialogues—with NASA engineers, safety personnel, and other relevant working-level staff. Two of these addressed the certification of CCP vehicles for human space flight, one addressed the Orion test program, one focused on the Orion and SLS flight certification program, and one addressed aeronautic flight operations.

Additionally, the ASAP and the NASA Advisory Council (NAC) initiated a cross-coordination effort with the chair of the ASAP and the chair of the NAC (or their designees) participating in each other's respective meetings in order to broaden the perspectives of each advisory group.

The assessments drawn from these activities will be provided in the following sections of this report, but we have some overall observations to note on the safety culture throughout the Agency.

Over the past several years, the ASAP has strongly championed the role of the Technical Authority (TA) as a major contributor to risk reduction efforts. Two years ago, the Panel was able to close a recommendation that addressed that role after the NASA Governance and Strategic Management Handbook was revised to reflect the question of how TA non-concurrences are handled and to add clarity to the TA appeal process. This year, we were pleased to see several examples where that process has been effectively executed.

Another area where the Panel notes a significant improvement is in the area of risk acceptance. NASA has historically demonstrated an exceptional capability to perform engineering analyses of potential risks and present the results for a decision. For a number of years, we have encouraged NASA to formalize the risk acceptance process with individual authority and accountability with the key elements of:

- unambiguous definition of the rationale for accepting risk, including stating the benefit to be gained;
- comprehensive examination of all alternatives;
- explicit addressing and documenting of the expected and potential consequences;
- transparent communication of the decision and reasoning among and between leadership and the workforce; and
- formal accountability by the responsible authoritative individual with signed documentation.

The Panel is pleased to report that during 2016, NASA has made substantial progress in this area. A very clear NASA Interim Directive (NID 8000.108) has been enacted, which effectively addresses our recommendation on this topic, and we have seen at least one excellent example of how a risk acceptance decision was vetted and properly documented. Over the coming year, we will monitor the risk acceptance process to gauge how effectively this new policy is being implemented across a broader spectrum.

As an indication of the health of the NASA safety culture, the Panel appreciatively notes that the Agency completed its fiscal year (FY) 2016 without a single Class A, B, or high-visibility mishap.

With respect to other ASAP recommendations, the Panel was able to close the recommendation that we made in 2015 concerning Orion risk assessment, and we continue to see excellent progress being made toward planning for the eventual safe deorbit of the ISS. Both will be discussed in following sections of the report. We have been in dialogue with representatives of the Agency on the recommendations for Radiation Risk Decision in Deep Space and addressing Human Space Flight Mishap Response Procedures. In both cases, there has been some progress, but more work remains.

The Panel has not been encouraged by the response to its recommendation on Knowledge Capture and Lessons Learned. The ASAP has strongly recommended a continuous and formal effort in knowledge capture that is highly visible and easily accessible. Initial efforts by the NASA Chief Knowledge Officer appeared promising but have failed to date to result in an Agency-wide, effective process.

The ASAP also made a new recommendation relative to asset protection, which will be discussed in this report.

III. Enterprise Protection

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 (EP) Program review at the ASAP's 4th Quarterly Meeting at JSC. 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.

NASA is now taking a holistic approach to asset protection. As briefed to the ASAP, there are three fundamental areas that comprise the enterprise: space and aerospace program asset protection, mission support infrastructure, and cyber security of institutional administrative networks. In the past, protection of these three areas has been managed somewhat in "stovepipes," with varying degrees of awareness and approach. Recently, NASA established a new position—the NASA Principal Advisor for Enterprise Protection. It is this individual's responsibility to advance the integration of asset protection across all NASA programs and foster a common strategy for cyber risk mitigation within NASA's mission programs. NASA has named this effort the EP Program, and its intent is to ultimately benchmark NASA protection practices with other governmental agencies.

Although NASA has a long way to go toward implementation, the EP Program has, in the Panel's view, a most appropriate vision. In the near term, the Principal Advisor for EP will focus on NASA-wide policy regarding security clearances for program managers, charter and establish an EP Program Board, define basic governance and semantics within the context of cyber security (e.g. "critical infrastructure"), expand NASA's current Space Asset Protection Working Group for more effective collaboration, and develop a protection program management model that is exportable to a broader suite of programs. To that end, the EP Program will leverage the successes of the Human Exploration and Operations Mission Directorate, which currently has a comprehensive approach to mission protection. In the longer view, the EP Program plans to become a more dynamic aspect of NASA's mission—as a policy developer that targets cyber risk management and as a facilitator of best practices across the Agency, commensurate with the security environment in which NASA operates.

The appointment of a Principal Advisor and the formal establishment of an EP Program is a positive first step. The Principal Advisor's commitment to establish a security clearance policy and to charter an EP Program Board, along with his experience with national security partners, are all highly encouraging signs. However, the ASAP is concerned that the EP Program is not a NASA program in the traditional sense, and the necessary resources required to begin protection improvements are not evident. The unique nature of cyber dictates that effective protection hinges on effective knowledge across the integrated enterprise. The Principal Advisor must work with a myriad of entities within NASA, providing effective influence on a culture challenged with old practices and ineffective integration. In the near term, it is imperative that the Principal Advisor has the resources to ensure that NASA managers have appropriate clearances to understand the threat environment in which NASA operates. At our 4th quarterly meeting, we formulated a recommendation on this topic.

> The ASAP recommends that NASA 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.

In addition to attaining clearances, an Agency-wide process to facilitate integration of the EP Program across NASA is also in progress. The Principal Advisor is now leading the development of a charter for an EP Board, comprising key NASA managers. In the longer view, the Office of Enterprise Protection, in a role akin to the three NASA TAs, must help NASA managers work together to "close the seams" between space/air assets, ground systems, and information technology networks, weighing choices of risk in design and operations across the enterprise. The ASAP will continue to monitor progress on NASA's Agency-wide process and its effectiveness.

In summary, while the Panel is impressed with the overall vision of the EP Program, our view is that the Principal Advisor for the EP Program does not have the manpower or resources to accomplish his near-term responsibilities in a timely manner. The apportionment of appropriate resources to this effort will be a major indicator of NASA's commitment to asset protection as a priority.

IV. Program Assessments

A. Commercial Crew Program

1. Management and Processes

The CCP is making steady progress toward its objective of providing the capability for near-term crew transportation to LEO and ISS. In prior years, the Panel had not experienced the degree of openness and transparency needed to properly assess this Program and provide appropriate advice. Last year, our annual report noted "substantial improvement in openness and interaction with CCP management." We are pleased to report that the openness and interaction have continued to increase. In our regular quarterly reviews, as well as a focused review on certification, CCP management has been extremely cooperative and responsive to our requests. This openness, by our observation, also extends to communications and data sharing with the commercial providers. The CCP has developed the access and insight into the providers' activities that it believes will be necessary in order to guide NASA's decision-making process.

As the CCP continues to progress towards finalizing the designs, the testing and evaluation of key hardware and systems certification have grown in intensity and importance. It is worth noting that certification represents the foundation upon which the suitability of the system rests. It encompasses a validation that all requirements have been properly covered and adjudicated between the provider and NASA. It means that the configuration of the system is known and fixed. The hardware and software in question must have complied with the adjudicated requirements, and its performance must have been validated in accordance with agreed-to testing, analysis, and/or other certification artifacts as delivered and approved. The ASAP stated in its 2015 Annual Report that the CCP had a well-defined and agreed-to process for achieving this result. While key technical issues remain and there is still work to be done, that process is being properly executed and there has been substantial progress.

In many cases, an improvement in both the quality and completeness of the submitted artifacts by both providers is apparent, although schedule continues to be a concern. As examples of the progress being made by both providers, virtually all requests for alternate standards have been received, and some 95 percent have been adjudicated and approved by NASA. The approval of these standards is basic to allowing the designs to proceed to completion. In addition to alternate standards, between 65 and 75 percent of all requested variances and Phase II Hazard Reports (HRs) have been reviewed by NASA and dispositioned. While the disposition of these items is taking longer than was originally anticipated, there has been substantial progress this year along with a marked increase in the quality and completeness of the submittals. However, based on the quantity of work remaining, there is certainly a very real possibility of future schedule slips.

In addition to the review of the submitted artifacts, the CCP safety process has also evolved. It is now entering the Phase II/III process, incorporating two dedicated safety boards—one for the spacecraft and one for the launch vehicle. These boards conduct a broad and detailed NASA team review of all HRs. There is a well-documented process to approve HRs and/or to elevate non-agreed HRs to

Figure 1. Boeing will be assembling and processing the Starliner at the former Orbiter Processing Facility-3, now known as the Commercial Crew and Cargo Processing Facility.

Figure 2. SpaceX has constructed a horizontal integration facility near Launch Pad 39A, planned to be used for commercial crew launches.

higher-level review. This process is fully implemented in accordance with CCT-PLN-1120, Section 4.5 and CCT-REQ-1130. This safety review process is a key element of the CCP certification approach and will result in the necessary verification closure of the Program's safety requirements.

There is no doubt that several key technical issues remain with both providers. They must be adjudicated before certification is complete and human flights can commence. NASA is aware of the providers' approaches and progress in these areas and continues to closely monitor results and testing to properly assess safety impacts and evaluate whether the providers' risk mitigations are adequate. Having a stable configuration will also be important. Despite some schedule challenges, the ASAP sees no evidence that needed safety considerations are being sacrificed merely to maintain schedule. In addition to our observations, CCP management has made it clear that they have no intention of approving any such reductions in safety efforts.

In summary, the Panel has observed an excellent certification process that is being properly executed by the CCP. Technical issues remain and hard decisions are yet to be made, but they are being worked inside that process.

2. Technical Challenges

Although progress is being made, there is still much left to do from a technical perspective. Whether the needed work can be accomplished without a substantial slip in the schedule remains to be seen. The Program is addressing several significant technical issues with each of the commercial providers. Some risk areas have been effectively mitigated and are no longer of serious concern. Others have mitigation plans that are well under way. A few, while being worked aggressively, remain challenging and of concern.

The top risks at the Program level are as follows: (1) the potential for requirements changes with associated cost and schedule risks, (2) the ability to close the gap in meeting the Loss of Crew (LOC) requirement, and (3) the disconnect between training hardware availability and the needs of the search and rescue providers. Mitigation for this latter risk is in work, and resolution is expected soon.

The ASAP was informed that the LOC goal of 1 in 270 may not be able to be met without additional spacecraft mitigations due to Micrometeoroid and Orbital Debris (MMOD)-associated risks, which are a dominant factor in the LOC calculation. Since the designs of proposed spacecraft systems are not fully mature and are still in a state of flux, it is impossible to determine what the final configurations will yield with respect to LOC. There may be a limit to what can be achieved by design considerations alone, and operational mitigations may be required to achieve the LOC goals. Also, we note that in considering LOC goals, we recognize that there is a fairly large uncertainty band around any calculated LOC number. This issue is currently under review and has the potential to impact budget, schedule, and crew safety.

A number of systems have not yet finalized design or completed testing. Challenges remain in several key systems, such as abort and parachute-related systems, in anchoring the analysis required to certify those systems for human flight. Additionally, there are issues and concerns surrounding the launch systems of both providers, such as the Centaur fault tolerance for Boeing and the "load and go" approach for SpaceX. ("Load and go" refers to a concept of operations in which the flight crew is strapped into the spacecraft prior to final fueling of the launch vehicle.) Both issues represent situations that are ultimately the result of the basic tenet of the CCP that puts the provider in control of the system design. NASA, in the oversight role of certification authority, determines if the hazards have been fully identified and the controls and mitigations implemented, and then decides if the resulting risk is acceptable. In this type of environment, the CCP must work diligently to ensure that acceptable risk is not defined by "the best we can do given the constraints." The residual risk must be openly acknowledged and elevated to the appropriate level within the Agency for consideration.

One complicating factor for the "load and go" issue is the potential uncertainty in hazard identification and control. Identification of the hazards is dependent on many factors, which include understanding the environment in which the system will operate. In this regard, the Panel is concerned that the dynamic thermal effects on the system associated with loading densified propellants may not be adequately understood, which results in a higher level of uncertainty that must be factored into the risk determination.

On September 1, 2016, during the preparations for a pre-flight static firing of its Falcon 9 launch vehicle, SpaceX experienced an anomaly that led to loss of the vehicle and payload. Although the activity was being conducted in support of a commercial satellite customer, both NASA and the U.S. Air Force (USAF) were invited to participate in the subsequent mishap investigation. The Panel has also been informed that NASA is doing its own independent review. These mishap investigations and determination of causes and contributing factors will not be completed until after this 2016 Annual Report is published. We believe that the focus of the investigation must not be solely to identify and fix the specific cause of this mishap. It must focus also on improving the understanding of how the system functions in the dynamic thermal environment associated with "load and go" so that other previously unidentified hazards can be discovered. This is not a trivial effort. Despite testing at the component and subassembly level, systems often display "emergent" behavior once they are used in the actual operational environment. We are concerned that any determination of risk associated with "load and go" would have significant uncertainty. For these reasons, we strongly encourage NASA top management to scrutinize this issue and ensure that any decision to accept additional risk or novel risk controls with large uncertainties is justified by the value that will be gained. The decision should not be unduly influenced by other secondary factors such as schedule and budget concerns.

Finally, discussion of CCP challenges would not be complete without mentioning the impact that interruptions to Government funding could have on the CCP schedule. Any such interruptions need to be carefully considered, not just because of the direct technical impact but also because of the implications for flight safety.

B. Exploration

1. Journey to Mars

During the past year, NASA has continued to focus its Exploration Systems Development (ESD) efforts on the systems and capabilities that will be needed for the Journey to Mars. The goal is to be able to send astronauts to the vicinity of the Red Planet or its moons sometime during the 2030s. Whether this would involve a fly-by, an extended period in Mars orbit, a landing on Phobos or Deimos, or actual "boots on the ground" on Mars has not yet been determined. NASA had previously published what it called a "detailed outline" of the necessary steps in preparing for such a mission. However, as the ASAP pointed out in its 2015 Annual Report, the level of detail in *NASA's Journey to Mars: Pioneering the Next Steps in Space Exploration* does not really allow a determination to be made on whether NASA would be able to successfully accomplish this type of mission in the desired timeframe, based on realistically attainable technologies and with budgetary requirements consistent with the current economic environment.

The Panel notes that significant progress has been made in identifying the needed capabilities, deciding on potential risk reduction strategies, and assessing the status of the specific technologies, including whether they are sufficiently funded. However, at some point, it will be necessary to provide a more focused evaluation of potential mission architectures in order to have confidence that the needed technologies have been properly funded and that they will be available in time to be incorporated into the actual flight hardware. Establishment of a Mars Mission Program Office and/or designation of a "Mars Czar" could facilitate the completion of the needed trade studies and ensure that limited funds are being spent on the appropriate technical challenges.

At this point in the process, no decisions on specific system architectures have been made. However, it is the Panel's understanding that even with a SLS lift capability of 130 tons, there would be a need for multiple launches per mission potentially augmented with the use of other vehicles such as the Evolved Expendable Launch Vehicle. With notional NASA out-year budgets assuming one SLS launch per year, plus the long trip times involved (800 to 1,100 days away from Earth), current plans to carry out the Journey to Mars appear to be somewhat "fragile." Since SLS would carry the most critical items into deep space, a delay or technical failure on a single launch could significantly impact the entire mission. This should make reliability a high priority for SLS.

One option to address this issue would be to take advantage of potential commercial and/or international activities to create a more robust exploration architecture. These commercial and international partnerships could also potentially provide opportunities for NASA to test technologies and systems on the lunar surface. Even if NASA chooses not to take a leadership role in human missions to the Moon, there may be other opportunities to gain valuable experience—with large landers and ascent vehicles, with the operation of systems for in-situ resource extraction, with large-scale habitation systems, and with the long-term impact of dust on space suits and other mechanical systems. Just as the ISS is an extremely valuable platform for testing advanced exploration systems in microgravity, the lunar surface offers an analogous opportunity for risk reduction and testing of surface systems that will operate in a challenging partial-gravity environment. Testing these systems first on the Moon could help to increase the robustness of the overall space infrastructure, enhance the cislunar space economy, and increase the safety of the Mars missions themselves.

2. Exploration Systems Development

(a). Test and Verification for First Crewed Flight

(1) Introduction and Background. In reviewing the ESD programs, the Panel once again focused on the certification path to the first crewed flight, currently planned for EM-2. In last year's report, we expressed concern that NASA had, primarily for schedule reasons, reduced the content and fidelity of the test and verification activities required for certification. Also, we were concerned that NASA had not fully assessed the aggregate increase in risk that was being accepted to hold schedule and content for EM-2. This resulted in the following recommendation being made to NASA in December 2015:

> The ASAP strongly recommends that NASA evaluate the combined effects and aggregate risk increase associated with the multiple changes to the Orion test and qualification plan. The Panel especially recommends that NASA review decisions that were driven, in part, by a constraint to hold the EM-2 schedule and content for 2021. As part of the review, the Panel recommends that

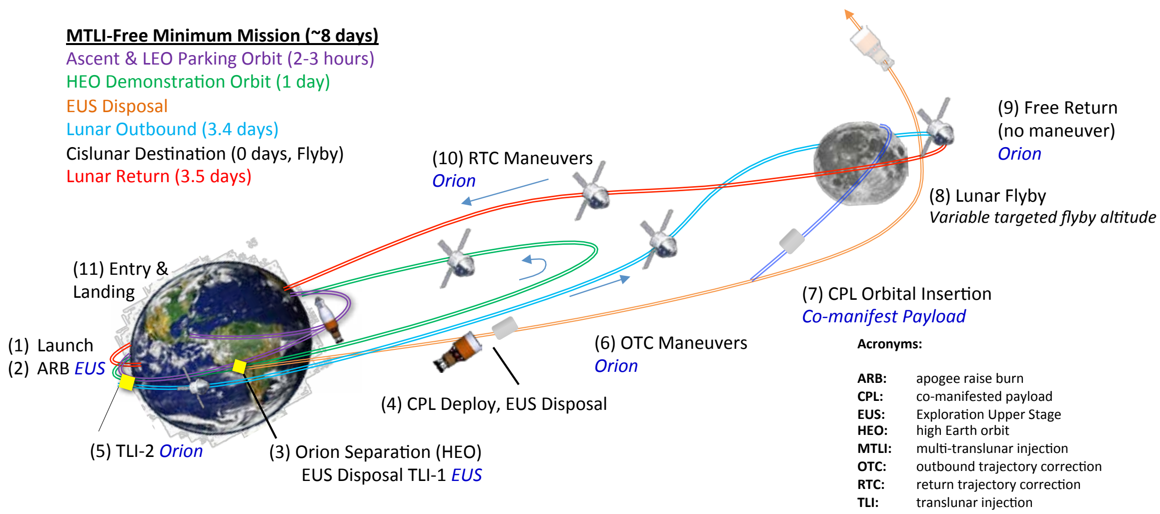
NASA fully assess the alternative of schedule relief and/or EM-2 content change as opposed to accepting the additional risk associated with the modified test/qualification.

Other issues the Panel committed to follow closely this year were: the changes to the Orion heat shield design; the resolution of "zero fault tolerant" failure modes of certain components in the Orion Service Module (SM); and the EM-2 mission profile considerations, given the fact that EM-2 would be the first flight of the Orion Environmental Control and Life Support Systems (ECLSS).

(2) Recommendation Status. In response to the recommendation, NASA and the Panel conducted a focused review in February 2016 on the Orion test and verification activities. Technical details previously unavailable to us were discussed in depth. The Panel's opinion—that the primary motivation for some of the changes was schedule and/or cost—did not change. However, it was acknowledged that many gaps in the certification plan were eliminated and some of the decisions would provide early data acquisition and potentially discover issues that might require a change to the design. While we do not fully agree with all the earlier decisions, it is clear that NASA understands the risks associated with the current test and verification plan. NASA's official written response to the recommendation did not detail how the alternatives of schedule relief and/or content change were assessed in the decision process, and we remain skeptical that those alternatives were fully considered.

On the positive side, the Panel has observed a noticeable change in the message coming from upper management concerning schedule pressure. While every program faces schedule challenges, the critical safety element is how the program responds to that pressure. The current message from management can be paraphrased as "be creative, but don't cut test or verification content." This is encouraging, but it remains to be seen if the message is absorbed and implemented throughout the workforce. In November 2016, we officially accepted NASA's response and closed the formal recommendation. However, we will continue to follow closely NASA's decisions as they deal with technical issues that present schedule challenges.

(3) EM-2 Mission Profile and First Flight of ECLSS. During the year, the Panel continued to follow closely the mission profile decision for EM-2. Because this is the first flight of the Orion ECLSS, there is a strong case for remaining in Earth orbit until confidence is gained that the life support systems are performing properly. On most mission profiles, Orion will use the SLS upper stage to provide the majority of the delta velocity necessary to go from Earth orbit to cislunar space. Therefore, remaining attached to the upper stage for extended periods of time in Earth orbit for ECLSS checkout presents some challenges—one being the risk of an MMOD strike to the upper stage. The decision to use the Exploration Upper Stage (EUS) on EM-2, instead of the Interim Cryogenic Propulsion Stage (ICPS), could potentially improve the MMOD risk. Additionally, NASA has developed a mission profile that seems to balance the competing interests by starting with approximately 3 hours in LEO, followed by 24 hours in an elliptical high-Earth orbit for checkout of ECLSS and other systems.



1-2) LEO parking orbit, 2 orbit checkout, and EUS "TLI"-ARB demonstration
3-4) Orion separates after majority of EUS TLI burn, achieves safe sep distance, EUS completes TLI-1 with disposal maneuver & deploys CPL
5) Orion flight test system characterization occurs in HEO (~24hrs), TLI-2 performed by Orion, initial mission duration fixed by target altitude
6) Option available to increase mission duration TLI-2 + 24hrs @ OTC-1 with fly-by altitude raise
7) CPL performs completely independent mission, non-critical path to mission success
8-9) Free return flyby, no Orion critical maneuvers required
10-11) Nominal mission return and cis-lunar entry velocity targeting San Diego vicinity

Figure 3. Multi-TLI - Free Concept of Operations

Orion would then perform a second Translunar Injection (TLI) burn for a free return lunar fly-by. Figure 3 depicts the mission profile, "Multi TLI – Free."

The NASA decision, with associated risk acceptance, was documented in a decision memorandum signed by the Deputy Associate Administrator for ESD at NASA Headquarters on October 24, 2016.

(4) Orion Heat Shield. In the 2015 Annual Report, the Panel noted that one of the most important lessons learned from the Exploration Flight Test-1 mission in December 2014 involved the Orion monolithic honeycomb Avcoat heat shield. Problems with cracks in the gore seams and reduced acreage material strength led NASA to switch to a molded block Avcoat heat shield design in early 2015. We were very interested in understanding how NASA would verify the bond between the molded block Avcoat tile and the substructure. There were areas where the structural stringers would preclude traditional non-destructive examination (NDE) techniques from beneath the substructure. Over the last year, NASA has made great progress with a new, ultrasonic NDE technique that can be used to verify the bond by "looking through" the Avcoat blocks from outside the heat shield. While NASA is still in the process of verifying that the ultrasonic NDE can detect the critical flaw size in the bond, everything so far looks promising.

Unchanged from last year is the question of whether a flight test of the new heat shield design is required prior to the first crewed mission. NASA has not formally stated a position to the ASAP on this question. Given current NASA plans, EM-1 is the only opportunity for such a test. We note that EM-1 is a very ambitious mission with many challenges. In our opinion, the test of the new Orion heat shield remains one of the most important mission objectives.

(5) Orion SM "Zero Fault Tolerant" Failure Modes. In last year's report, the Panel reported on Orion SM systems that were zero failure tolerant. In some scenarios, a single failure could result in the loss of crew and vehicle. The example cited was in the SM propellant storage and delivery system, which has six latch valves (three oxidizer and three fuel) directly tied to the bulk propellant storage tanks. Each of these valves has a seal that is zero fault tolerant to leakage as well as a mini bellows that is also zero fault tolerant to leakage. Should any one of these valves develop a leak in either the seal or bellows, all usable SM oxidizer or fuel (depending on the specific valve) will eventually leak out of the system. This would leave the Orion SM with no ability to control attitude or perform in-space maneuvers—a potentially catastrophic failure. In the current design, the SM propulsion tanks cannot be isolated to minimize the effects of a leak. NASA committed to addressing these issues in 2016 and reached a decision in March to improve the failure tolerance of the valve seals, bellows, and sensors for EM-2 (in addition to incorporating a helium cross-feed capability). NASA also committed to a more significant propulsion system upgrade on EM-4 that provides additional system robustness by incorporating a parallel propulsion feed system and addresses continued improvements in failure tolerance. All the NASA TAs and the crew office agreed with this decision as the appropriate path forward resulting in acceptable risk for propellant leaks on the first two crewed flights (EM-2 and EM-3) and further risk reduction for EM-4 and subsequent missions. The decision, as well as associated risk acceptance, was documented in a decision memorandum signed by the Deputy Associate Administrator for ESD at NASA Headquarters on March 28, 2016.

The Panel recently learned that the failure tolerance improvement for the bellows leak failure case is more technically challenging than previously thought and may not be ready for EM-2. Therefore, NASA is revisiting the implementation schedule for this improvement with potential incorporation on a later mission. While acknowledging that the mission profile for EM-2 [section 2.*(a)*.(3) above] could potentially mitigate some propellant leak risk, there is a significant difference between technical information that changes the understanding of risk and technical information that reveals the schedule cannot be met. We will be closely following the resolution of this issue in the coming months.

(6) Exploration Upper Stage. Previously, the Panel expressed some concerns with human rating the existing ICPS of the SLS. Therefore, the Panel was pleased to see NASA commit to the EUS, shown in Figure 4, at the earliest opportunity, since NASA will be able to incorporate its human-rating requirements into the design.

The first flight of the EUS is currently planned for EM-2, which is also the first flight of crew. As this approach will not provide a flight test of the new upper stage before a launch with crew onboard, the ground test and verification plan is of considerable interest. Details were not available prior to this report, but we will be following closely the environment in which the ground test and verification plan is developed. Since flying crew on the first flight of an upper stage is a significant decision, the plan should reflect the best judgment of the engineering and safety community on what is necessary to achieve an acceptable level of risk. Once that is determined, the plan should then be evaluated from a schedule perspective. However, if the team is initially handed a constraint of “give me the best plan that fits into the 2021 schedule,” we would be concerned that schedule could potentially affect the definition of acceptable risk.

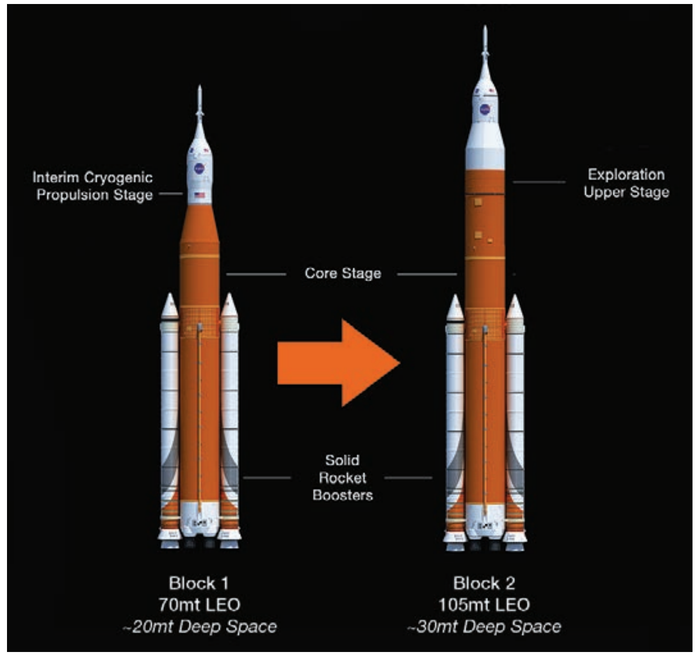


Figure 4. SLS Configurations

(b). Certification Complexity

In October 2016, NASA and the Panel conducted a focused review of the formal flight certification process for Exploration Missions. The typical certification flow, shown in Figure 5, has three distinct phases: (1) Design Certification, (2) System Acceptance, and (3) Flight Readiness.

In an ideal world, these phases happen mostly serially with little overlap. With a stable design, only System Acceptance and Flight Readiness are repeated for each mission; but in reality, designs evolve and this invokes a requirement for a “Delta Design Certification” prior to flying the new design. This will likely happen frequently for the early Exploration Missions, because the docking system and SM propulsion system improvements will be incorporated into Orion. What is particularly challenging for the certification of EM-1 is the amount of overlap in the three phases, as illustrated in Figure 6.

This approach, which is required to meet the schedule for EM-1, has design and acceptance activities overlapping and not completed before the Integrated System Acceptance Review or, in some cases, before mating the major flight hardware components in the Vehicle Assembly Building. NASA openly acknowledges the complexity of this approach, the fact that it is schedule-driven, and the programmatic risks. The Panel also believes that the significant overlap could make it more difficult for senior leadership to fully understand the overall risk being accepted at each milestone and the potential for an unrecognized accretion of risk, as we highlighted in our report last year. NASA will need to be extremely vigilant and disciplined throughout this process.

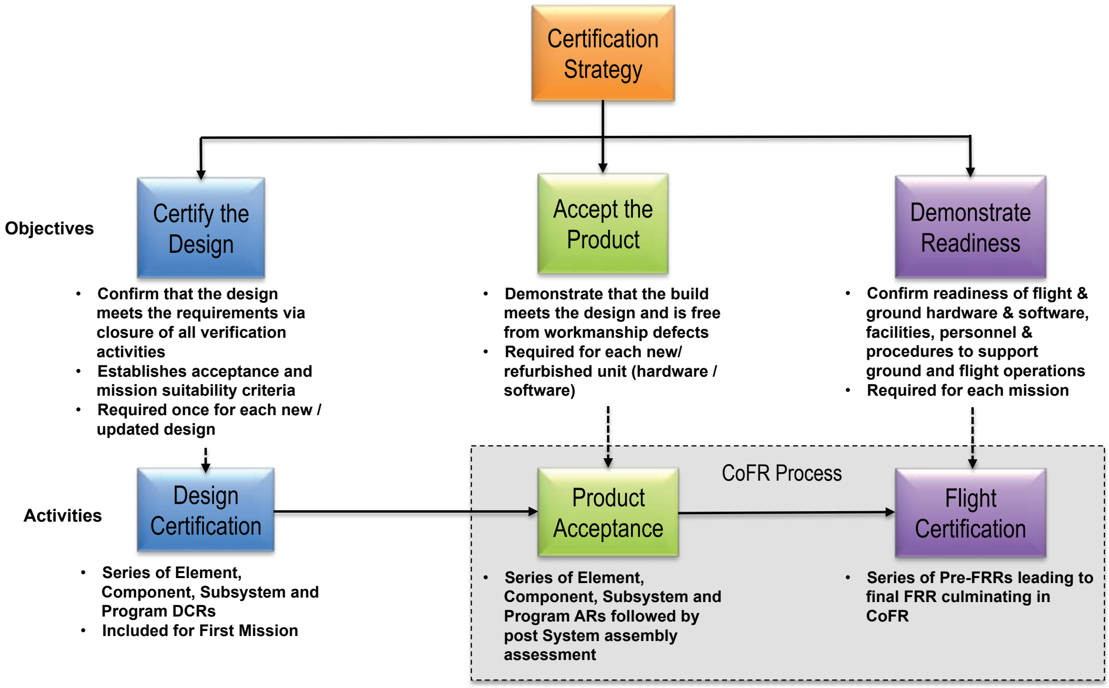


Figure 5. Typical NASA certification flow

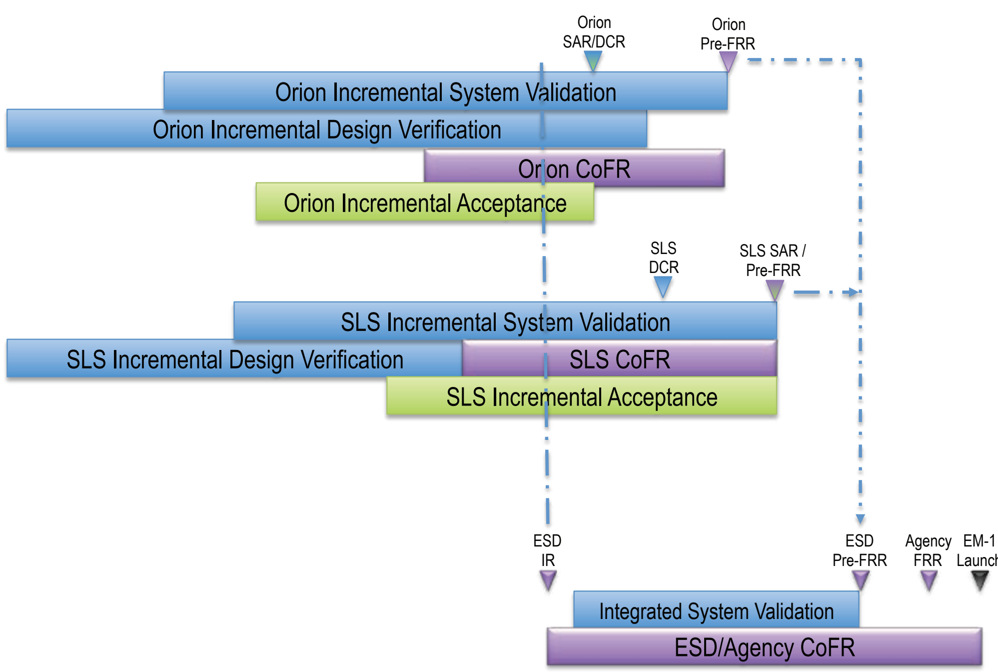


Figure 6. Overlapping EM-1 certification activities

C. International Space Station

Figure 7. ISS in orbit

The ISS Program continues to impress the ASAP with its ability to effectively deal with expected and unexpected challenges in an exemplary manner. This level of performance is a credit to the Program as a whole, as well as the individuals at all levels. The entire ISS team has consistently delivered this level of performance despite changes in senior leadership and reflects very positively on the well-organized system that they have put in place.

While multiple recent launch failures have impacted the delivery schedule of commercial cargo flights to ISS, sound planning by the ISS Program has proactively dealt with the logistical contingencies. These launch failures also validate NASA's wisdom in having multiple options for cargo delivery to the ISS. NASA's recent decision to specify the use of an Atlas V for a commercial cargo delivery flight to the ISS in order to provide a higher confidence of successful logistics support—despite a higher cost—demonstrated to the ASAP a proactive approach to managing risk. We will continue to monitor the most recent SpaceX failure that occurred during a pad test to ascertain whether it will have any impact on the CCP's ability to meet crew transportation needs after the planned end of the Soyuz service contract in 2018.

In addition, the Program continues to leverage the ISS crew and capabilities to mitigate risk to long-duration exploration. For example, issues related to extra-vehicular activity (EVA) hardware were effectively handled and demonstrated the value of ISS as an experiment and test platform suited to exploration risk mitigation.

Another activity to support future exploration needs is the deployment of the Bigelow Expandable Activity Module (BEAM). This is a promising technology demonstration designed to investigate the potential challenges and benefits of expandable habitats for deep space exploration and commercial LEO applications. Expandable habitats are designed to take up less room when being launched but provide greater volume for living and working in space once expanded. During the BEAM's two-year test period, the module will be isolated from the rest of ISS with only the occasional crew entry (three to four times per year) to facilitate interior structural inspections and environmental data collection. After the test program, BEAM will be jettisoned from the ISS and disposed of by re-entry burn, similar to how the Progress modules are treated. This first test of an expandable module will allow investigators to gauge how well the habitat performs and, specifically, how well it protects against solar radiation, space debris, and temperature extremes. As a potential high-value design option for weight-saving strategies for exploration, the BEAM Program is an ideal fit with the ISS Program goal of critical technology investigation.

Figure 8. BEAM being installed on the ISS by the Canadarm

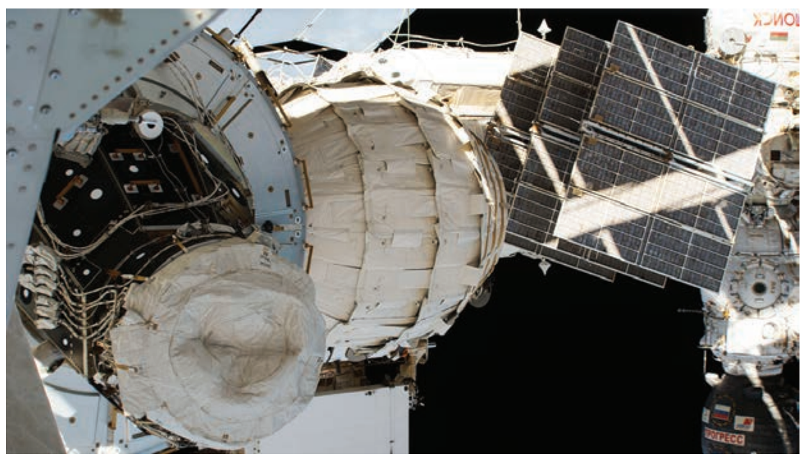


Figure 9. Expanded BEAM berthed to the ISS Tranquility node

The ASAP applauds the ISS Program's focus on risk reduction for the safety and mission assurance of the Exploration program. We encourage strong continued and systemic synergy to meet the challenges ahead as NASA further prepares for exploration beyond LEO.

For the past two years, the ASAP has pointed out the need to complete the planning for an ISS emergency deorbit contingency. While NASA and its partners have made much progress in developing these plans, they are not yet complete. An ISS End Of Life (EOL) Strategy Document and Contingency Action Plan (NASA changed the name of this activity to "ISS Deorbit Strategy and Contingency Action Plan" in December 2016) has been jointly developed but has not been formally adopted, as per NASA's schedule. Required software modifications are currently in development. Most importantly, a new ISS Deorbit Strategy Project Manager position, reporting directly to the ISS Program Manager, has been created to oversee completion of a comprehensive plan to perform a contingency ISS deorbit. In the worst case, such a scenario may be not only necessary but time-critical. Deliberate planning for such time-urgent emergencies is a well-known NASA operational strength, and we will continue to monitor progress of the planning until successful completion.

Finally, the candor and transparency with which the ISS Program communicates with ASAP regarding its operational plans as well as its current and anticipated challenges further reinforces the confidence we have developed in the ISS program. We will carefully follow potential future vulnerabilities that were identified by ISS management, such as future funding adequacy in FY17 and FY18, EVA-related concerns, and lack of assured access to ISS in 2019.

D. Aeronautics and Air Operations

1. Introduction

Aeronautics and air operations were addressed on several occasions during the reporting period. The Panel was briefed on the utilization of the NASA Aircraft Management Information System (NAMIS), an interest area continued from our 2015 Annual Report. In addition, we had an opportunity to review the advanced aeronautics work being done in support of the SLS Program and to hear about a new, advanced aeronautics initiative called "New Aviation Horizons." The Panel held two insight trips associated with air operations—one to Armstrong Flight Research Center (AFRC) and one to Ellington Field, the flight facility for JSC. In addition to reviewing the operations themselves, we inquired into the status of their use of NAMIS, a critical component of maintaining aircraft maintenance/material and operational safety.

2. NASA Aircraft Management Information System (NAMIS)

NAMIS, as mentioned in last year's report, provides the sole basis for certification of continued airworthiness for NASA aircraft. It holds the official record of each aircraft's configuration, compliance with inspection requirements, parts replacement requirements, and compliance with any hazard bulletins or reports. NAMIS is the tool that holds the information that validates if an aircraft is, in fact, in certification for flight.

The critical importance of aircraft certification cannot be over emphasized. Certification for flight means that the configuration as recorded has been validated as airworthy and that the specific aircraft matches that configuration precisely. Any variations from the official record would be a significant violation of aircraft safety management. The "dual requirement" is: (1) the configuration as recorded in NAMIS has been certified as airworthy in the validated airworthiness process, and (2) the aircraft precisely matches that configuration. Violation of either of these conditions would violate the airworthiness certification of the aircraft. In addition to aircraft certification, at the larger aircraft operations Centers—JSC and AFRC—NAMIS is used on a limited basis to produce "work packages" (step-by-step maintenance procedures derived from electronic technical publications) for maintenance personnel to follow while working on the aircraft. The other Centers that have aircraft operations are using hard-copy-only maintenance publications. Although there is no mandate to use online technical publications, it is a "best practice" for aircraft maintenance. If the requirement were present, funding shortfalls would not allow for NAMIS to support online technical publications for the other Centers. The additional safety risk with paper publications is the delay in critical updates to technical publications.

In addition to airworthiness, certification, and maintenance support for flight, NAMIS is the primary means by which NASA flight crewmembers track flight time, currency, and qualifications.

Clearly, this makes NAMIS the critical information technology (IT) backbone of NASA flight operations and aircraft maintenance; therefore, its support is vital. NAMIS is a standalone, IT system with oversight from the Agency Applications Office, sponsorship from the NASA Chief Information Officer and NASA Aircraft Management Division, and operated and managed by JSC's Aircraft Operations Division. The Aircraft Operations Division has had to struggle for funding, using "sweep-up" funding in many instances to maintain functionality of the NAMIS system. This situation is not appropriate for such a critical safety system.

Given the crucial nature of the NAMIS system, the Panel is very concerned that funding for this system remains in doubt, especially in future years. In our view, NAMIS must be fully funded *and* vigorously used and maintained to ensure safe aircraft operations. Resource constraints in this area are being felt across NASA. For example, the NAMIS support office at JSC had to reduce staffing this year to remain within budgetary constraints. This has impacted their ability to make timely software updates. Overall, program funding has been levied at about 80 percent of estimated need. Continuous resource support must be allocated to operate, maintain, and modify (as needed) the NAMIS system. In addition to allocating required resource support, continuous management vigilance is required to ensure that its use by all NASA aircraft operators and maintainers is mandated and enforced. To our knowledge, the future budgetary shortfalls identified in our 2015 Annual Report (up to 46 percent through FY 2019) have not been eliminated or addressed. From a safety perspective, this represents a significant potential risk.

3. Aircraft Operating Facility Visits

The Panel visited two important aircraft operating facilities this year—the AFRC facility and Ellington Field. At AFRC, we were invited to see two research aircraft that are currently in use to support sensor development, environmental research, and astronomy. The multi-sensor DC-8 is utilized in support of the development of a wide variety of measuring devices to record changes and levels in the atmosphere, pollution levels, sea ice extent, and other critical Earth measurements. The Stratospheric Observatory For Infrared Astronomy, a Boeing 747 aircraft-based system, utilizes a large, onboard infrared telescope to view events in space in support of scientific missions. Both programs were being well executed and providing both exciting and crucial data and information to their respective science organizations. With regard to the use of NAMIS, AFRC reported that the system was being used and was mandated, but they had requested numerous changes to better support their activity and those changes still needed to be incorporated.

At Ellington Field, the emphasis was more on the training program for astronauts and the support of the human space flight program. For training, the facility operated 18 T-38 supersonic jet trainers and 3 WB-57F high-altitude aircraft. In addition, they also operated two Gulfstream commercial passenger jets engaged in astronaut recovery from Russia and some limited sensing support to NASA programs. Finally, they operated the unique NASA "Guppy" aircraft, a heavily modified cargo plane designed to carry high-volume payloads (outsized cargo). Currently, this aircraft is used in support of the Orion Program to carry the Orion spacecraft. At Ellington Field, the Panel was especially interested in how they were dealing with airframe structural aging issues that have been identified for the T-38 aircraft originally designed and built in the late 1950s and 1960s. After reviewing their activities, we are pleased to note an excellent program has been put in place. It is being executed to both maintain the aircraft and to ensure replacement of key critical components as needed. We were especially pleased to see that the maintenance and engineering team at Ellington has maintained close contact with both the USAF "Pacer Classic II" program and the U.S. Naval Test Pilots School, both of which are also dealing with aging airframe issues on the T-38. In addition, Ellington Field has developed several innovative training programs or hands-on training experiences for both pilot and non-pilot astronauts. These experiences cover more than the necessary pilot flying hours. They provide experiences covering flight operations, maintenance, aircraft operation, and pressure suit training. We found these programs to be both innovative and commendable. Regarding NAMIS, Ellington Field was using the system, and it was mandated for use. The schedule backup on requested changes was due to funding constraints, but they are being executed as fast as possible.

4. Aerodynamics Support to SLS

In aerodynamics, the Panel was pleased to have the opportunity to review two separate developments. The first was a key area where aerodynamics is contributing crucial information into the SLS Program. In this development, we were briefed by the SLS Lead Engineer for Aerodynamics and Acoustics on how computational fluid dynamics (CFD) and wind tunnel testing were being used as complementary tools for understanding SLS/Orion aerodynamics during launch and ascent. CFD is sometimes thought to be able to fully replace wind tunnel testing. However, under many circumstances, this is not correct. Experience shows that wind tunnel testing demonstrates superior results when CFD is too expensive, takes too long, or the flow is in areas where CFD cannot provide a confident solution. For SLS/Orion, the place where CFD has the most difficulty providing confident solutions is in unsteady aerodynamics. This region includes two key areas. The first is the area of buffet, which is a low-frequency, unsteady shock oscillation that can drive significant structural loads and bending moments. The second area is aeroacoustics, a higher frequency phenomenon that can cause local structural failures and panel oscillations. Obviously, both these flow areas are critical to the structural design of the SLS/Orion system. Finally, CFD has difficulty with wind loads due to the normally very low velocities. This can result in problems with rollout and while the rocket is sitting on the pad before launch. These regions clearly pose some level of risk to the system and must be mitigated by design to ensure crew and system safety. Wind tunnel testing best serves to understand the flow in these regions and predicts the impact on the system. We were pleased to note that NASA was using both CFD and wind tunnel testing, as well as all its available tools, to understand and address these aerodynamic risks. Results are used to effect system design and enhance system safety for the astronauts.

5. New Aviation Horizons Initiative

The second new development is NASA's New Aviation Horizons Initiative. The Panel was briefed on this initiative by the Associate Administrator for the Aeronautics Research Mission Directorate.

The program highlights NASA's increased emphasis in aeronautics, air traffic management, aircraft environmental impact, and advanced aircraft technology, including supersonic flight and new configurations. This is an exciting new program that has as its overall objective "U.S. Leadership for a New Era of Flight." The potential impact of this program for the country is substantial. NASA provided data showing a potential growth prediction for the global aviation industry of nearly 4 billion passenger trips in the next 20 years.

This initiative will start a continuing series of experimental aircraft to demonstrate and validate high-impact concepts and technologies. Five major demonstrators, commonly referred to as X-planes, are proposed over the next 10+ years, focusing on ultra-efficiency, hybrid-electric propulsion, and low noise supersonic flight. NASA's investments in cutting edge aeronautics research today are intended to provide a cleaner, safer, quieter, and faster tomorrow for American aviation. The need for this initiative to maintain a strong emphasis on flight safety is not limited to the vehicles themselves. One key objective is to develop the needed technology and systems so that the air transportation system can absorb nearly four billion more passengers over the next 20 years without compromising the safety of our skies. This substantial increase in the capability of the air transportation system, including traffic control both in the air and on the ground, represents a significant safety challenge, and the program must pursue the needed technology for such a

Figure 10. U.S. leadership for a new era of flight

capacity increase. The Panel will continue to monitor and review this initiative in the future to ensure that such emphasis is maintained.

In addition, the Panel notes that this initiative includes experimental aircraft, concept demonstrators, and modified aircraft used to demonstrate advanced technology. As with other experimental flight programs, considerable effort must be devoted to flight safety. This includes both air and ground crew safety as well as public safety. NASA, in the past, has put in place robust processes and procedures to ensure that such experimental research flying is conducted in a safe manner. However, programs of this type have been rare in recent years, and these procedures will need to be reviewed and updated to reflect modern technology and risk mitigation. Ensuring that this effort is not overlooked and reflects the appropriate incorporation of such safety processes will be an area of our oversight as the initiative proceeds.

As described in the initial plan, the effort can provide potential positive impact on the technologies that affect both the air transportation system and the millions of passengers who utilize it every day. The Panel would urge NASA to ensure that the needed safety considerations are reflected in the program execution plan as the Agency moves forward. Assuming proper safety considerations are taken into account, this initiative appears to have high potential for positive impact to an important transportation system. Given the fact that this program involves experimental research flight operations with both new and modified aircraft with their attendant risks, sufficient budget must be provided to ensure that safety does not become a tradeoff due to lack of resources.

V. Summary

Twelve topic areas, highlighted in this report, are summarized in the table on the following page. They have been broken out to focus attention on individual topics that the Panel feels are worthy of note.

Of the twelve topic areas, two are rated as **RED ■**, indicating they are long standing and have not yet been adequately addressed. This year, both red-rated issues are related to funding.

The topics highlighted in **YELLOW ▲** are important issues or concerns that we are not confident are being addressed adequately by NASA. These issues will continue to be followed and examined closely by the Panel.

Four topics are labeled as **GREEN ●**, which indicates a positive aspect or concern that is being adequately addressed by NASA, but continues to be followed by the Panel.



Topics	2016 Assessment
■ Impact of Continuing Resolution (CR) Funding	Uncertainty with the exact budget and partial release of funds as the CR unfolds adds complexity to managing programs and executing long-lead acquisitions. This can distract teams from maintaining the required focus on safety. This burdens constancy of purpose and may threaten mission assurance.
● Managing Risk with Clear Accountability and Formal Risk Acceptance	NASA has made progress on this long-standing concern. A clear interim directive has been issued that meets the key elements identified by the Panel. We look forward to its implementation in the field and will continue to monitor this area. While steps have been put in place to properly vet and accept risks, incremental risk is still being accepted in isolation. NASA is encouraged to continue to focus attention on total system risk.
▲ Human Space Flight Mishap Investigation Planning	The Panel has recommended that the language in the NASA Authorization Act of 2005 requiring a Presidential Commission investigation in all cases involving loss of flight crew as well as cases involving loss of vehicle, be reviewed and modified. The goal should be to have an independent review by qualified individuals in a thorough but expeditious manner. NASA is drafting language for consideration by the Panel.
▲ Enterprise Protection (EP)	NASA is now taking a holistic approach to asset protection. Recently, a new senior staff position was established to advance the integration of asset protection across all NASA programs and foster a common strategy for cyber risk mitigation within NASA's mission programs. The ASAP is encouraged by the EP Program vision and the preliminary steps taken. However, we are concerned that the Principal Advisor for the EP Program does not yet have the necessary resources or manpower to accomplish his near-term responsibilities in a timely manner.
● Commercial Crew Management and Processes	Openness and interaction have continued to increase. The Commercial Crew Program (CCP) has developed the access and insight into the providers' activities that it believes will be necessary to guide NASA's decision-making process. While key technical issues remain and there is still much work to be done, there has been substantial progress. The ASAP has observed a well-defined and agreed-to certification process that is being properly executed by the Program.
▲ Commercial Crew Technical Challenges	The CCP is addressing several significant technical issues with each of the commercial providers. Some risk areas have been effectively mitigated, others have mitigation plans that are underway, and a few remain challenging and are of concern. A number of systems have not yet finalized design or completed testing. Both providers' launch systems still require additional work before either system can be certified for flight by NASA.
▲ Exploration—Journey to Mars Plan	NASA has made some progress in defining the Journey to Mars, but in the opinion of the Panel, current plans lack substantive risk reduction, technology maturation, and advanced systems development to achieve the stated goals. Establishing a Mars Program Office could facilitate these efforts. We encourage NASA to take advantage of potential commercial and/or international activities to create a more robust exploration architecture.
▲ Exploration Systems Development (ESD)—Program Schedule Impact on Safety	Last year, the Panel expressed concern that NASA was making changes to the Orion Test and Verification plan primarily to maintain the 2021 launch date for EM-2 and did not assess the cumulative risk associated with those changes. After conducting two focused reviews and a noticeable change in the message from senior leaders, we have closed the recommendation. However, it remains to be seen if NASA's commitment to "not cut technical content to hold schedule" will hold as the programs deal with the technical challenges noted this year.
▲ ESD—Certification Complexity and Risk Accretion	NASA certification approach for EM-1, which is required to meet the schedule, has design and acceptance activities overlapping and not completed before the Integrated System Acceptance Review, or in some cases before mating the major flight hardware components in the Vehicle Assembly Building. The significant overlap could make it more difficult for senior leadership to fully understand the overall risk being accepted at each milestone and the potential for an unrecognized accretion of risk as the Panel highlighted in its report last year.
● International Space Station (ISS)	ISS continues to be a "good news" story. There have been challenges with resupply, but the Program has planned appropriately and overcome them through multiple suppliers and good on-board logistics management. The Station is being used to provide opportunities for learning and application for the Journey to Mars. Deorbit planning is heading on the right path and now has a designated Project Manager to provide even more focus and emphasis. An ISS deorbit action plan has been developed jointly with the partners and is awaiting formal adoption and signature. The required software modifications are underway.
■ Funding Adequacy for NASA Aircraft Management Information System (NAMIS)	Adequate funding for NAMIS was highlighted as a serious issue in last year's report and remains a concern. Future budgetary support at an appropriate level to maintain NAMIS is uncertain and represents significant potential risk for safe Agency-wide aircraft operations. NAMIS remains the primary IT system for determining aircraft configurations, documenting airworthiness compliance, conducting routine maintenance, and recording flight crew currency/qualification. Use of NAMIS should be standardized across all Agency flight operations Centers and should be robustly supported as a critical Agency IT system.
● New Aviation Horizons Initiative	This initiative will start a continuing series of experimental aircraft to demonstrate and validate high impact concepts and technologies. Investments in this initiative are intended to provide for cleaner, safer, quieter, and faster American aviation.

Appendix A

Summary and Status of Aerospace Safety Advisory Panel (ASAP) Open Recommendations

2016 Recommendation

2016-04-01

Asset Protection—Security Clearance Policy: 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.

OPEN The Principal Advisor of the Enterprise Protection Program has been tasked to respond to this recommendation. He has reported that the Office of Protective Services (OPS) has direct responsibility on security clearances within NASA, and other intelligence agencies have the authorities overall; therefore, it will take some coordination to provide a response. The Principal Advisor met with OPS on October 27, 2016, but the ASAP did not receive a response from NASA before this report went to print.

Open Recommendations from Prior Years[1]

2015-05-02

Human Space Flight Mishap Response Procedures: The Authorization language should be reviewed with today's systems in mind. Also, more details appear appropriate for the NASA implementation document. These details would include the level of vehicle damage requiring investigation, the temporal issues of when mission phases begin and end, and NASA's oversight role in mishap investigations conducted by its providers, as well as when the need for outside oversight is required. The mishap response procedures should be thought through, documented, and in place well before any actual flights.

OPEN NASA's original response to the ASAP on April 30, 2016, was that the Agency was reaching out to the Federal Aviation Administration (FAA) and the National Transportation Safety Board (NTSB) to jointly develop viable options to revise the Authorization language with today's systems in mind. The NASA Human Exploration and Operations Mission Directorate (HEOMD) reported at the third quarterly meeting of 2016 that the effort was on-going and provided tentative language. NASA predicts they will have proposed language by end of 2016.

2014-01-01

Radiation Risk Decision on Deep Space Mission: The ASAP recommends that (1) NASA continue to seek mitigations for the radiation risk and (2) establish an appropriate decision milestone point by which to determine acceptability for this risk to inform the decision about a deep space mission. This risk choice should be made before NASA decides to go forward with the investment in a future long-term mission.

OPEN NASA originally responded on April 24, 2014. The Office of the Chief Health and Medical Officer (OCHMO) briefed the NASA implementation plan response to the recommendations in the Institute of Medicine (IOM) Study to the ASAP on October 28, 2014, at its fourth quarterly meeting. The ASAP was complimentary of the plan and said in its response dated November 17, 2014, that NASA should adopt the process as briefed. OCHMO had the action to brief the implementation plan to the Agency Program Management Council. Once complete and the associated decision memo signed, OCHMO was to develop the appropriate OCHMO procedural requirements. OCHMO briefed the Panel again at the second quarterly on May 10, 2016, on the plan for

1 *Note on color highlights:* ■ Red highlights what the ASAP considers to be a long-standing concern or an issue that has not yet been adequately addressed by NASA. ▲ Yellow highlights an important ASAP concern, but one that the Panel is not yet confident is being addressed by NASA. ● Green indicates a positive aspect or a concern that is being adequately addressed by NASA but continues to be followed by the Panel.

implementing recommendations from the IOM report, "Health Standards for Long Duration and Exploration Spaceflight Ethics, Principles, Responsibilities and Decision Framework." The Panel had a favorable response and is still awaiting NASA policy and guidelines for implementation of these plans.

2014-01-02

Knowledge Capture and Lessons Learned: The ASAP strongly recommends a continuous and formal effort in knowledge capture and lessons learned that will make them highly visible and easily accessible. Modern tools exist to facilitate this and NASA should avail itself of them. NASA's Knowledge Management system should include risk-informed prioritization of lessons and a process to determine which lessons have generic (vs. local or project unique) potential. Further, it should be supplemented by formal incorporation into appropriate policies and technical standards of those lessons that are most important to safety and mission success. Rigor in this area is particularly critical as the experience in specific skills dissipates over time and as engineering talent is stretched across programs.

OPEN NASA originally responded on March 27, 2014. The NASA Chief Knowledge Officer (CKO) briefed the ASAP on February 10, 2015. The ASAP changed the status to green with the understanding that the completion of a formal policy by the CKO in the future would close this recommendation. The CKO again briefed the Panel at its 2016 first quarterly meeting. The Panel was not convinced that NASA has found a sufficient method nor adequate tools for sharing information and again urged the Agency toward continued improvement. The status was downgraded to red.

2014-AR-05

Processes for Managing Risk with Clear Accountability: NASA should consistently provide formal versus ad hoc processes for managing risk with clear accountability.

OPEN NASA originally responded on July 22, 2014, and provided an updated response on January 22, 2015. ASAP chose not to close this recommendation, and in its February 24, 2015, letter addressing the status of recommendations, changed the item to yellow, stating that the proposed NASA change to single risk acceptance is the right step and will close upon completion of the policy. The Office of Safety and Mission Assurance (OSMA) presented at the second quarterly meeting of 2016, and later met with the ASAP Chair for input into updated policies. OSMA released an interim directive, NID 800.4, Agency Risk Management Procedural Requirements, in September 2016. This Interim Directive will serve to implement a formal process for risk acceptance. ASAP awaits the release of the subsequent update of the NASA Procedural Requirement (NPR) to close this recommendation.

2012-01-02

International Space Station (ISS) Deorbit Capability: (1) To assess the urgency of this issue, NASA should develop an estimate of the risk to ground personnel in the event of uncontrolled ISS reentry. (2) NASA should then develop a timeline for development of a controlled reentry capability that can safety deorbit the ISS in the event of foreseeable anomalies.

OPEN NASA originally responded on May 9, 2012. ASAP decided the recommendation would stay open until ISS had a timeline for implementing a deorbit plan and the deorbit plan was in place. HEOMD began working this action when assigned in 2012. There are many aspects to implementing the deorbit plan, including working with international partners. It is estimated that it will take 1-2 years to implement the plan after the schedule is determined. At the 2016 first quarterly meeting, the current ISS Program Manager briefed the Panel on the status of the deorbit plan. In January 2016, the Russians had received direction to restart End-of-Life (EOL) production development. In March 2016, a Technical Interchange Meeting was held to move the EOL activities forward. The ISS briefings at the third and fourth quarterly meetings of 2016, showed further progress; however, the plan is still not complete. At the next quarterly meeting (first quarterly meeting of 2017), ISS will offer a timeline chart. Current predicted completion of deorbit capability is no earlier than September 2017. ISS will continue to brief the ASAP on a quarterly basis on the status of this recommendation.

Appendix B

Closure Rationale for Recommendations Closed in 2016

2015-05-01

Orion Risk Assessment: The ASAP strongly recommends that NASA evaluate the combined effects and aggregate risk increase associated with the multiple changes to the Orion test and qualification plan. The Panel especially recommends NASA review decisions that were driven, in part, by a constraint to hold the Exploration Mission (EM)-2 schedule and content for 2021. As part of the review, the Panel recommends that NASA fully assess the alternative of schedule relief and/or EM-2 content change as opposed to accepting the additional risk associated with the modified test /qualification.

> **CLOSURE RATIONALE:** In addition to performing the recommended risk evaluations and assessments of alternatives, the Panel has observed a positive change in NASA management's message in regards to dealing with schedule pressure. Protection of test and verification content appears to have been given the appropriate priority by leadership. The remaining challenge for NASA is to ensure this message is clearly understood by the entire team. The Panel will continue to watch how NASA deals with schedule pressure, but this specific recommendation is closed.

2012-03-05

Five-Year Roadmap for Continuous Improvement of the Agency's Mishap Investigation Process: NASA should continue to report to the ASAP on the training of the Mishap Investigation Team (MIT) and the investigation Board Chairs in greater detail to include the method, consistency, and quality of training for MIT members and Board Chairs.

CLOSURE RATIONALE: The ASAP held its 2016 first quarterly meeting at Kennedy Space Center, February 22–24, 2016. The Panel greatly appreciated the participation and support that was received from the subject matter experts and support staff. At this meeting, the ASAP closed Recommendation 2012-03-05, “Five-Year Roadmap for Continuous Improvement of the Agency’s Mishap Investigation Process.” The Panel stated in the minutes of the meeting that NASA appears to have a solid roadmap.

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