Aerospace Safety Advisory Panel

Annual Report for 2014

NASA AEROSPACE SAFETY ADVISORY PANEL
National Aeronautics and Space Administration
Washington, DC 20546
VADM Joseph W. Dyer, USN (Ret.), Chair

January 28, 2015

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 of 2005 (P.L. 109-155), the Aerospace Safety Advisory Panel (ASAP) is pleased to submit the ASAP Annual Report for 2014 to the U.S. Congress and to the Administrator of the National Aeronautics and Space Administration (NASA).

This Report is based on the Panel's 2014 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.

The ASAP applauds NASA's accomplishments during this past year. These include safe International Space Station (ISS) operations, growing traction on the Exploration Systems Development programs, success in supporting ISS logistics via commercial cargo, and positive strides in infrastructure management.

Regrettably, the Panel is unable to offer any informed opinion regarding the adequacy of the certification process or the sufficiency of safety in the Commercial Crew Program (CCP) due to constraints on access to needed information.

In this Report, we note that NASA is experienced and accomplished in procuring space systems by "making" (e.g., NASA custom-produced satellites), "managing" (e.g., a NASA program office managing fulfillment of a "performance spec," often designed and generally produced by a contractor), and "buying" (where the marketplace has established the bona fides of value, safety, and reliability).

The CCP falls within a chasm between the deep insight of "managing" and that of "buying" a product proven by broad market acceptance. With the CCP, NASA is operating at relative arm's length while concurrently fostering the development of a commercial market. The Panel strongly believes open communication and transparency are essential to ensuring the safety of the program.

NASA's senior leaders and staff members offered significant cooperation to support the completion of this document. I submit the ASAP Annual Report for 2014 with respect and appreciation.

Sincerely,

VADM Joseph W. Dyer, USN (Ret.)
Chair, Aerospace Safety Advisory Panel

Enclosure

NASA AEROSPACE SAFETY ADVISORY PANEL
National Aeronautics and Space Administration
Washington, DC 20546
VADM Joseph W. Dyer, USN (Ret.), Chair

January 28, 2015

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

Dear Mr. President:

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National Aeronautics and Space Administration
Washington, DC 20546
VADM Joseph W. Dyer, USN (Ret.), Chair

January 28, 2015

The Honorable John A. Boehner
Speaker of the House of Representatives
Washington, DC 20510

Dear Mr. Speaker:

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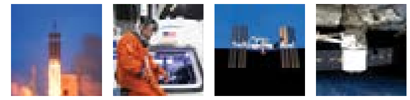
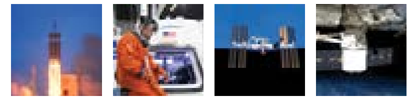
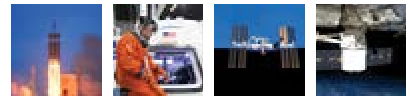




Preface

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 all the recommendations submitted to the Administrator during 2014 is included as Attachment 2 on the CD. They 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

In this 2014 Annual Report to the NASA Administrator and to the Congress, we again highlight the mismatch between the breadth of the Agency's undertakings and the funding available to execute them. The resources necessary to safely and efficiently accomplish the full scope of scientific discovery, aeronautics research, and further extension of the Nation's reach into the solar system are insufficient. This is especially true as NASA has started developing the equipment that will carry Americans to Mars concurrently with extending the life of the International Space Station.

The Panel notes the many NASA human space flight programs that have been initiated in the last 20 years but not carried to completion. The ASAP appeals for "constancy of purpose" and observes that this objective is both important and challenging when there is a change of leadership in either the Congress or the White House.

Within NASA, there are outstanding examples of programs that have inculcated a culture of clear and candid communications. Their approach to accountability, good systems engineering, and respect, both up and down the organization chart, would find strong favor with the authors of the Columbia Accident Investigation Board Report.

The Commercial Crew Program (CCP) is an exception to the culture of open communication. Regrettably, the Panel has been denied the necessary timely access to information and is therefore unable to offer any informed opinion regarding the adequacy of the certification process or the sufficiency of safety in the CCP. The NASA Administrator has committed to making the changes necessary to resolve this situation and to ensuring that these barriers are removed going forward into 2015.

The Space Launch System and Orion programs are well underway and have captured the interest of the American public and raised morale across the Agency. The ASAP is closely following these programs and expresses concern that the Loss of Crew probability thresholds for them are not significantly safer than the actual historical performance of the Space Shuttle.

The Panel commends NASA's continued use of unfunded Space Act Agreements to stay engaged with evolving, privately funded commercial space companies.

II. Accomplishments in 2014

A. International Space Station (ISS) Operations and Utilization

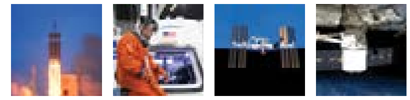
The Panel has been impressed with the detail, openness, and transparency with which ISS status, problems, analyses, solutions, and risks have been discussed. Although there are some concerns (discussed in Part III.E of this Report), as there will be in any large, operational human space flight program, anomalies have been well-handled by the team, and the ISS Program appears to be very well-managed. Significant milestones this year included 14 visiting vehicle dockings, approximately 3,000 hours of research, and 328 hours of extravehicular activity from the U.S. Orbital Segment. A very busy manifest has challenged the Program, and the teams have been successful in both flight and ground operations. NASA has made substantial progress on planning for the safe deorbit of the Station at end-of- life. The ASAP was again impressed with the number of countries participating in the Space Station and how well they work together, not only on routine tasks but on problems and challenges.

B. Milestones in Exploration Systems Development (ESD)

NASA continues to make progress on its flagship human exploration activity, which consists of three programs: Orion, including the crew module, the service module, and the launch abort system; the Space Launch System (SLS), which is the new heavy-lift, exploration-class rocket; and Ground Systems Development and Operations (GSDO). Orion's first flight test, Exploration Flight Test (EFT)-1, was launched December 5 on a Delta IV Heavy launch vehicle from Cape Canaveral Air Force Station and recovered successfully from its Pacific Ocean splashdown by NASA's GSDO and the U.S. Navy. EFT-1 tested many of Orion's key subsystems, including its heat shield, electronics, and parachutes. In August, NASA completed a rigorous review of the SLS and approved the Program's progression from formulation to development. The Michoud Assembly Facility in New Orleans completed the installation of all assembly tools, including the largest friction stir welding tool in the world. All solid rocket booster segments have been poured and are ready for hot case qualification test in 2015. NASA completed the initial design and technology development phase for the GSDO Program in March. The Vehicle Assembly Building at Kennedy Space Center has undergone modifications and upgrades to support the lifting needs for SLS and Orion.

C. Milestones in Commercial Cargo and Commercial Crew to Low-Earth Orbit

Under Commercial Resupply Services (CRS) contracts, both Space Exploration Technologies Corporation (SpaceX) and Orbital Sciences Corporation (Orbital) continued cargo missions to the ISS. SpaceX and Orbital each flew two successful CRS missions. Orbital's third CRS mission, launched in October, suffered catastrophic failure shortly after liftoff; however, there were no injuries, and the launch processes and safety protocols protected the public. Orbital and the Federal Aviation Administration, with NASA and National Transportation Safety Board support, are conducting the mishap investigation. Orbital has publicly committed to make any required changes necessary to resume cargo missions and expeditiously continue the program.



This was a significant year for the Commercial Crew Program: several key reviews and tests were completed under the current Space Act Agreements (SAAs), final deliverables under the Certification Products Contracts were dispositioned by NASA, and awards of the Commercial Crew Transportation Capability contracts to SpaceX and The Boeing Company were made in September. These contracts include NASA certification of the commercial systems, test flights with crew on board to the ISS, and post-certification missions for regular ISS crew transportation.

D. Marshall Space Flight Center (MSFC) Infrastructure Management

The Panel was pleased to note an innovative and successful approach to managing the limited infrastructure maintenance budget at MSFC. An individual with a strong program management background has been placed in charge of facilities management and is applying classical program management techniques to optimizing the use of available resources. Through such techniques as "repair by replacement" and prioritizing facilities maintenance in line with mission priorities, MSFC is actually reducing its deferred maintenance backlog. While NASA as a whole clearly has a serious budgetary facility-maintenance shortfall, including significant environmental cleanup needs, the techniques being used at MSFC to optimize limited resources are applauded, are exemplary, and should be expanded throughout the Agency.

E. Technical Capabilities Assessment

In 2013, NASA senior management kicked off an Agency-wide Technical Capabilities Assessment to establish a more efficient operating model that maintains critical capabilities and meets current and future mission needs. One of the challenges is to integrate the critical capabilities in a way that avoids unnecessary duplication and takes advantages of the synergies that already exist. The trade between competition-driven duplication and designating a Center for performing certain types of work is neither simple nor easy to implement, and the ASAP applauds NASA for taking on this challenge. Through the efforts of the Technical Capabilities Assessment Teams, the Agency is making decisions about capabilities and solutions based on future and current mission needs. In 2014, the initiative moved into decisions on solutions. The assessment has already had a positive impact on aircraft operations.

F. Other Commercial Space Developments

NASA has done an excellent job of encouraging companies to maintain communications and relationships with NASA programs by maintaining competition where possible on major programs, by providing "on-ramps" for potential new providers, and by being open to both funded and unfunded SAAs.

G. Other Accomplishments

Other noteworthy NASA events over the past year include the continued robotic exploration of Mars, a number of successful technology demonstrations, the launch of several Earth science missions, and continued progress in developing the next generation of air transportation systems.

III. Issues and Concerns

SUMMARY ASSESSMENT

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 or issue, but one that is currently 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. ♦ Gray signifies insufficient data for the Panel to make an assessment at this time.

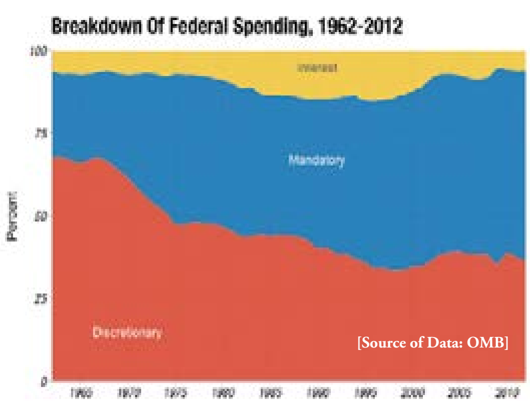
Issues	2014 Assessment
▲ Constancy of Purpose	NASA and its stakeholders should unambiguously articulate a well-defined purpose for the human space flight program. More importantly, there should be constancy of purpose, without which there are deleterious impacts on cost, schedule, performance, safety, and workforce morale. NASA's current capabilities-based approach appears to be budget-driven instead of a purposeful, schedule-driven, goal-oriented endeavor.
■ Risk Transparency—Insight and Communication	Risk transparency, especially regarding explicitly accepted, unmitigated risk, is paramount to the management of NASA's space flight–associated activities. Risk communication concerning commercial crew activities by the Director of Commercial Spaceflight Development has been less than forthcoming. Because Probabilistic Risk Assessment results provide a risk assessment of the design capability at maturity, actual risks for early operations of the Space Launch System (SLS) and Orion could be significantly higher than the calculated or "advertised" risk. Because the perception of external stakeholders is vitally important, NASA's Office of Communications must be cautious not to create or reinforce inaccurate perceptions of risk.
▲ Candid Mishap Investigation and Reporting	NASA's process for mishap investigation is vulnerable to influences that could undermine full discovery of a mishap's causal factors. The releasable nature of mishap report information and potential release of privileged witness statements open the possibility of filtered information and a focus on blame over cause.
▲ Culture	Although NASA conducts "culture surveys," there does not appear to be a comprehensive, Agency-wide process to measure changes over the long term.
● Technical Authority	Progress has been made. The cultural impacts are of particular interest to the ASAP.
● International Space Station (ISS)	While there is clearly work ahead to develop strategies for best utilizing limited ISS cargo delivery capabilities and to complete safe ISS deorbit planning, the ISS Program continues to exemplify a well-managed program. The ISS has the potential to serve as an excellent test bed for future exploration activities. A formal plan that establishes the ISS's role in the future development of exploration technologies would both greatly support exploration and provide constancy of purpose for the ISS Program.
▲ Exploration Systems Development (ESD)	Orion, SLS, and Ground System Development and Operations are making continued progress, but the Panel continues to be concerned about ESD integrated risk and the current thresholds for the SLS/Orion system on launch and recovery. Risk on the Exploration Mission-2 flight is a concern—it bundles a number of new systems together with the first crewed mission. The ASAP and the Agency remain concerned about the low frequency of SLS/Orion launches. Much work needs to be done in defining and evaluating risks and the "road to Mars," but NASA is addressing these risks and should continue to communicate them openly and transparently.
● Commercial Cargo Resupply Services	Despite the Orbital mission failure in October, there were four successful commercial cargo missions to ISS in 2014. However, both commercial cargo providers have struggled to meet NASA's desired launch dates. There will be additional pressure on ISS logistics while Orbital works through its plan to resume cargo missions.
♦ Commercial Crew Development	The Panel is concerned that the Commercial Crew Program may not be sufficiently funded to meet its contractual obligations. Even with sufficient funding, there are significant challenges ahead. Because of a lack of transparency within the Commercial Spaceflight Development Division at NASA Headquarters, the Panel is unable to assess the safety or planned NASA certification of the commercial system.

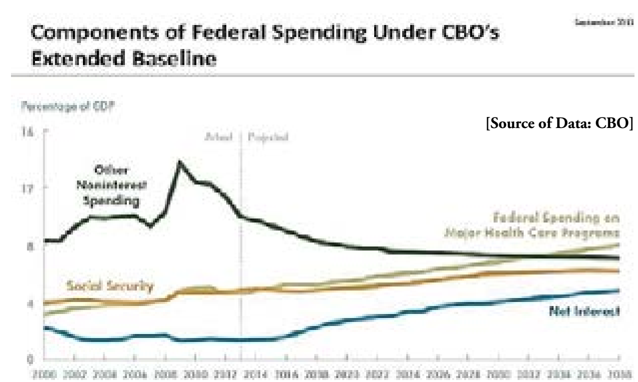
A. Constancy of Purpose

In its 2013 Annual Report, the ASAP noted a concern regarding a perceived lack of a well-defined mission for NASA's space program. The Panel advised that absent a well-defined mission, it is impossible to either efficiently or effectively plan, develop, build, test, validate, and launch the necessary system to achieve "something" that is not clearly described. Such vagueness of purpose also makes it difficult to budget, request and defend funding, retain stakeholders' interests and support, and motivate and maintain an effective workforce.

The Panel recommended in the 2013 Report that NASA clearly define missions, objectives, and requirements for both performance and certification. Without this level of clarity, it is impossible to determine what level of safety risk is acceptable because that determination is based on a value decision that balances the risk of potential negative consequences against the potential gains. The ASAP continues to believe that it is imperative that NASA unambiguously articulate a well-defined purpose, including a path toward the execution of that mission, the technologies that need to be developed and matured, and the resources needed to accomplish that mission.

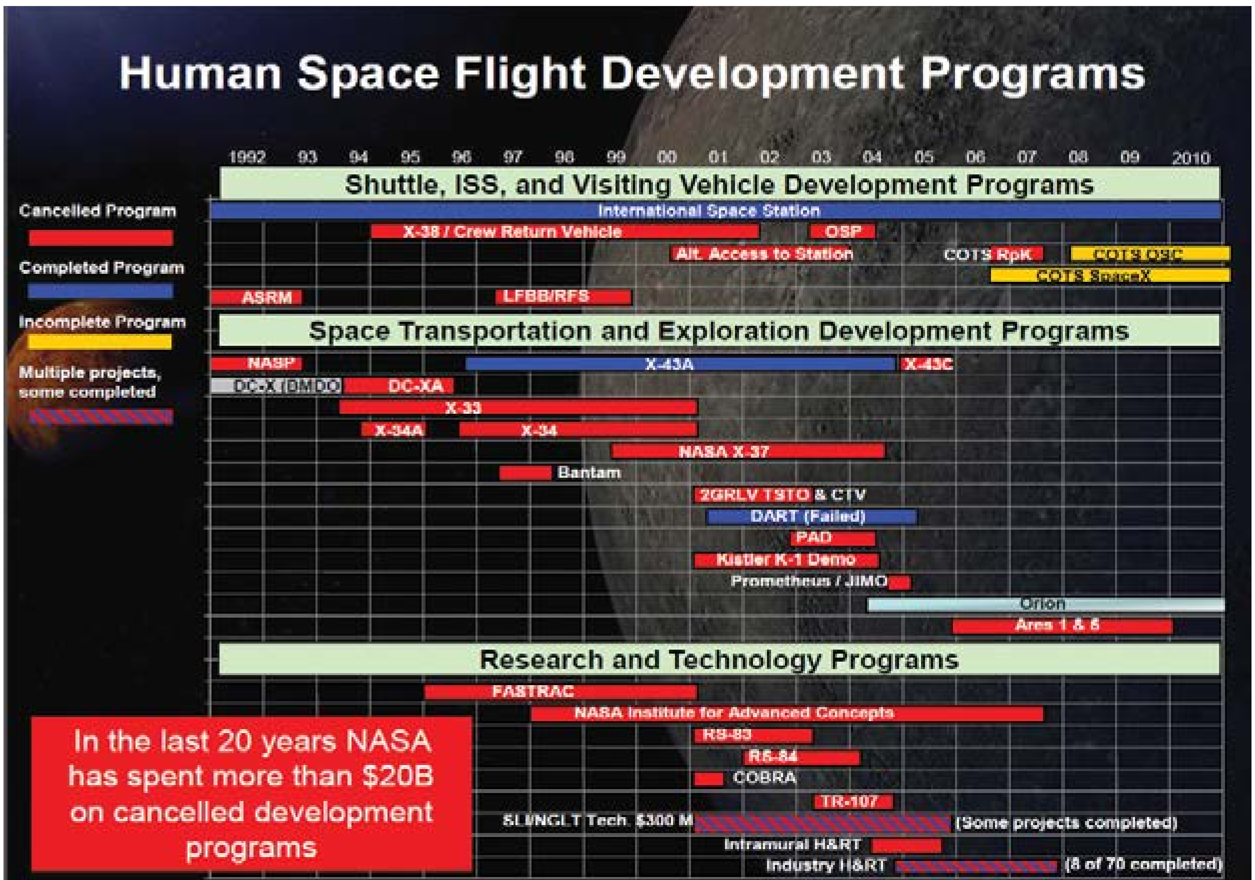
Since the days of Apollo, the Nation's discretionary resources have diminished considerably, and the portion of that budget available for NASA to achieve anything along with them. (See Figures 1 and 2 below.) As the Congress debates the Nation's fiscal future, NASA will need to show the value of its efforts for the economy and demonstrate good stewardship of funds, including progress toward achieving a clear and well-articulated purpose whose benefit is clearly stated.





Figures 1 and 2: Federal Spending History and Projection.

However, clarity of purpose and goal is not enough; equally, or possibly more important, is constancy of purpose—a steadfastness in pursuing the articulated goals that does not waver with time. Without such constancy, there is deleterious impact on cost, schedule, performance, safety, and workforce morale. The negative impact does not stop there, however, because such instability can destroy credibility with industrial partners, the Congress, and the public. This, in turn, can undermine support, which then leads to more disruption of planned programs and further magnifies the lack of constancy of purpose. These conditions can degenerate into a vicious cycle resulting in the ultimate canceling of a program and failure to achieve mission and goals, as has happened many times in the past. Figure 3 illustrates the cost impact of starts and stops in the development of human space flight programs. Additionally and importantly, the continual launching of new initiatives means increasing risk by once more introducing new, unknown risks instead of sustaining a learning curve on a consistent development path. Clearly, the utility of NASA's investment would be improved by completing programs of record versus the restarts that too often follow Administration change.



[Source: Marcia S. Smith, "Did NASA Really Waste $20 Billion in Cancelled Human Space Flight Programs?" http://www.spacepolicyonline.com/news/did-nasa-really-waste-20-billion-in-cancelled-human-space-flight-programs, *September 22, 2012] Graphic originally appeared on Representative John Culberson's Web site, visited September 22, 2012.*

Figure 3: Cost Impact of Starts and Stops in Human Space Flight Development Programs.

A clearly articulated and constant purpose can remain that way only through the support of a reliable source of funding. Absent funding of a consistent and adequate level, NASA is forced to constantly juggle its support of programs in a manner that negatively impacts the ultimate cost to completion, mission success, and safety. The Panel recognizes that constancy of purpose is not solely the responsibility of NASA; rather, it is an accountability that is shared with those external stakeholders. What is needed is a lasting consensus among the Administration, the Congress, and NASA on a genuine long-term mission and vision, combined with provision of the required funding.

NASA's current response to the lack of support for an explicit and concrete mission has led the Agency to adopt what is termed to be a "capabilities-based approach" to build enduring capabilities, consistent with budget constraints, intended to allow humans to explore beyond low-Earth orbit (LEO) with Mars as a "horizon goal." The approach is three-pronged with (1) Earth reliant capabilities (LEO); (2) a proving ground for further-reaching capabilities (cislunar), including the Asteroid Redirect Mission (ARM); and (3) Earth independent, on the road to Mars.

A capabilities-based approach is one that builds pieces of a system that may be needed to undertake multiple and varied missions but is not a grand goal to be accomplished on a specific schedule. It lacks the focus and the crispness of the planning and the budget that go with a program like Apollo, but it may build capability that is sustainable with the budget that is available.

NASA's current capabilities-based approach appears to the ASAP to be budget-driven instead of a purposeful, schedule-driven, goal-oriented endeavor. We believe that it reflects an attempt, in the face of limited fiscal support, to sustain continued movement forward to maintain capability, develop infrastructure, and gain experience without declaring a desired end objective. While this approach may help preserve capabilities, the ASAP is concerned that NASA risks under- or over-investing in technologies that may or may not be necessary, and it may fail to develop mitigations for risks that pose significant hazards on some missions but perhaps not others. Without constancy of purpose—perhaps out of an apprehension that declaring an objective or purpose would necessitate a commitment of will and resources that would not be supported by external stakeholders—NASA could risk the loss of consistent support, and stakeholders could perceive that there are no long-term goals worthy of enthusiasm and support.

This capabilities-based approach could bridge a transition between administrations. It is less than one might want it to be, but it is pragmatic and realistic, and it flows from the budget challenge. The ASAP believes, however, that in dealing with its budget realities, NASA would be better served to prioritize and set aside programs, activities, and infrastructure of lesser importance. In other words, focus on doing fewer things and on doing them better.

The consequences of not sustaining a clear and constant purpose are reflected in more than monetary impacts. With each reset of the program, there is an associated delay in achieving any goal and, inevitably, extended schedules. If resources are not allocated in the appropriate years/phases of a program, normal progression is not made, which causes enormous additional costs as resources are not efficiently expended. And, without a focus on a clear and consistent goal, schedule is frequently a casualty. The ASAP is concerned that both Orion and the Space Launch System (SLS) may be vulnerable to these consequences. NASA recently indicated that the first

SLS launch will not happen until late 2018—perhaps not until 2019—rather than the 2017 target—basically more than a 1-year slip. There are also likely to be very few test launches possible within the development program, leading to increased risk on each flight.

In addition to the impacts mentioned above, a lack of clear and constant purpose also creates a potential cost of lost opportunities—or not effectively or efficiently using available resources. An example is seen with the International Space Station (ISS). The ISS represents a remarkable potential capability for proving out or exploring technologies needed for human space exploration. NASA has announced its intent to extend the lifetime of the ISS, but the importance and relevance of that extension to support a clearly defined mission have not been clearly articulated. Without an unambiguous vision for the future, a valuable and costly resource may be underutilized, support from international partners may erode, and dollars that might be applied in more effective ways will be wasted. Meanwhile, we are risking the safety and long-term health of the ISS crews without gaining the full benefit from their efforts.

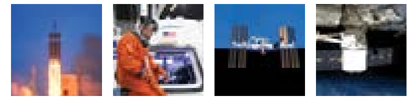
Without constancy of purpose, there are also personnel impacts. Talented and dedicated engineers, testers, and resource analysts become discouraged when their efforts are perceived as futile or pointless. "Brain drain" and the loss of both experienced and youthful professionals is a likely result over the long run.

When constancy of purpose is threatened by resource shortfalls, it often impacts the choice of approach to achieve objectives. To achieve a goal of transportation to LEO, NASA has chosen a different business model than in the past. A simplistic view of the choices would be whether to make, manage, or buy a capability.

These three approaches are summarized in the table below.

Make	Manage	Buy
Characterized by customized products, perhaps one customer with unique requirements, specs, and design. The customer owns the design.	Characterized by products for which there is a limited but still somewhat open market. Still a Statement of Work, specs, and significant involvement by the customer, but the design is constrained by existence of products in adjacent markets.	Characterized by a larger number of customers and suppliers with very little customization of the product. May be selected from a portfolio of what is available in the market. Mature. Often fixed price.
Examples: Mercury, Gemini, Apollo, Mars Curiosity	Examples: Launch vehicles, solid-propellant rocket motors	Examples: Commercial satellite launch services

The distinctions between the three approaches often blur, but one usually dominates. NASA, within a constrained budget, is attempting to approach the commercial crew transportation requirement as "buying a service," yet the maturity of the product may be more suitable to a "managed" development. NASA is making a laudable effort to embrace this new business model but is caught somewhere in the transition between managing



and buying. The ASAP remains concerned with the inherent risks of this approach. To succeed, NASA and its stakeholders need to recognize the state of maturity of the methodology and mitigate the risks accordingly.

Another threat to constancy of purpose is the reaction to inevitable failures along the way. When the goal is clearly and unambiguously understood and articulated, the risks and value of the endeavor are transparently communicated, those risks are mitigated or transparently accepted, and failures are not considered as major setbacks but as normal or expected occurrences in difficult endeavors. Rather than canceling a program or coming to a prolonged standstill after a failure, an appropriate reaction—given constancy of purpose—is to learn from the failure, fix any problem expeditiously and responsibly, and continue. The ASAP believes that this is the approach being taken with respect to the recent Cargo Resupply Services (CRS) launch failure and supports it.

In summary, the ASAP reiterates its recommendation from last year: NASA—and its stakeholders—should clearly define its missions, objectives, and requirements. Once defined, all should resist changing those elements because of the negative consequences for cost, schedule, performance, and risk. Further, the Panel highlights three possible methods to mitigate the current situation: (1) prioritize and set aside programs, activities, and infrastructure of lesser import, i.e., do fewer things better and faster; (2) improve the utility of NASA's investment by completing programs of record versus the restarts that too often follow Administration change; and (3) form a lasting consensus among the Administration, the Congress, and NASA on a genuine long-term mission and vision and provide the funding required to deliver.

B. Risk Transparency—Insight and Communication

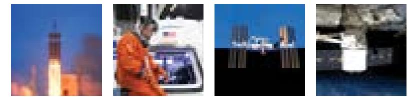
1. Clear and Candid Communication

Clear communication is an essential and foundational component of any undertaking, and its importance is directly related to the complexity, hazard, and risk associated with the task or mission. NASA's space flight–related activities fall into the category of complex, hazardous, and risky undertakings that require explicit and timely communication. NASA's successful management of space flight programs is absolutely dependent on having straightforward, intra- and inter-organizational, risk-related communication upon which to base decisions. In addition, NASA is also dependent on clear and candid communication concerning risk to external stakeholders—such as the public, the Congress, and the media—since these outside stakeholders' perceptions of the risk involved in space flight–related operations will heavily influence their opinion of NASA's competence as well as their support of NASA in the event of a mishap. This open and unambiguous communication of the risks involved is often termed "transparency."

Any undertaking is always subject to some level of risk that things may not come out as planned. The risk of failure is never zero. This is especially true for NASA's space flight–related activities. To effectively reduce the risk of negative outcomes, the hazards and the probability of their occurrence must be clearly understood by all parties so that well-informed risk mitigation strategies can be formulated and implemented. Put another way, you can't fix what you don't know about. This need for transparency of risk—especially explicitly accepted, residual (unmitigated) risk—is paramount to the appropriate management of NASA's space flight–associated activities.

For the ASAP to fulfill its charter to aid NASA in the achievement of safe operations, it is imperative that the risks attendant with NASA programs be transparently shared in a timely manner. With timely input, the ASAP can provide advice so that it can be considered by NASA in a proactive manner to adequately address safety. Otherwise, if not transparently given information in advance, the ASAP is reduced to the less desirable function of providing criticism after a problem has already occurred. The ASAP has generally been very pleased and impressed with the candid and transparent manner in which NASA has communicated risk-related information. Examples of outstanding performance in this regard are the communication between Panel members and NASA senior leaders such as the Administrator, the Associate Administrator, and the Associate Administrator for the Human Exploration and Operations Mission Directorate (HEOMD), all of whom have impressed the ASAP with their candor and commitment to the transparent communication of risk. Similarly, programs such as the ISS, through its Program Manager and his team, have never ceased to impress the ASAP with their candor and transparency of communication regarding the risks and problems that have been encountered and their risk mitigation strategies. Such open communication not only allows the ASAP to function in a more productive advisory manner—rather than taking a "Monday-morning-quarterback" critic role—but it also develops a level of trust that enhances the operation of the entire enterprise.

There are certain areas where this exemplary behavior of candid, timely, and transparent communication of risk has been insufficient. The Commercial Crew Program (CCP) has been notably less forthcoming. This lack of transparency has been a concern for a number of years and, despite numerous discussions with the Director of Commercial Spaceflight Development (DCSD) and with senior leadership at NASA Headquarters, this less-than-candid and -transparent communication with the ASAP regarding the CCP has persisted. Over the last several years, the DCSD has responded to ASAP's requests for information related to the plans on how commercial programs would be certified or how confidence would be gained on the safety of operations with a seamless set of constraints as to why the information could not be shared. These have ranged from "we're still defining the acquisition approach" to "that information is pre-decisional" to "the investigation is still being conducted" to "that's source selection sensitive information" to "a protest has been filed." While these statements are all true, these conditions should not be absolute barriers to sharing information related to certification and safety. The responses by the DCSD have generally been a compilation of all the reasons cooperation was not possible rather than figuring out how to make things work. Even when subordinates of the DCSD give briefings to the ASAP, there is often obvious concern about how to answer the Panel's questions. For example, the subordinate looking at the DCSD, apparently seeking permission and/or guidance prior to answering a probing question, may be a symptom of an environment where the culture is not one of openness and can lead to poor internal and external communication. For all of these reasons, the ASAP is currently unable to offer any informed opinion regarding the adequacy of the certification process or the adequacy of the level of safety in the CCP. The ASAP has been requesting this safety and certification information for 3 years, but it was only after the Panel made it clear that this failure to share information would be covered in this Report that an offer was made to



supply some information for review. In mid-December, the ASAP finally did receive some contract deliverables, and the Panel will evaluate this information; however, it was too late to be incorporated in this year's Report. Unfortunately, it was also too late to have allowed the ASAP to provide timely advice to the Program during the extremely critical early planning and development process. The actions of the DCSD in interacting with the ASAP, which were also noted during the development phase of the Commercial Cargo Program, have created a challenging environment that has the potential to increase risk. The Panel is concerned that this lack of candor is not limited to interactions with the ASAP and may extend to other internal and external stakeholders. This opacity and failure to engage in open and transparent communication is reminiscent of the problems that were explicitly identified by both the Rogers Commission and the Columbia Accident Investigation Board (CAIB) regarding causes of the Space Shuttle Challenger and Columbia mishaps respectively.

2. Probabilistic Risk Assessment Methodology

A cornerstone of risk management for high-consequence operations such as human space flight is the analytical assessment of the risks being considered. One critical tool for such analyses is the Probabilistic Risk Assessment (PRA). Versions of this tool have been used for decades in numerous industries, and it has proven very valuable for quantifying the risk being considered. To use this tool, the analyst first attempts to identify the failure modes that can result in the "Undesired Event" and then assesses their likelihood using historical reliability information. In NASA human space flight, the Undesired Event is often considered Loss of Crew (LOC), and the unit of measure for probability is the likelihood of such a catastrophe on any given flight. One difficulty in applying this type of analytical tool is that it can assess only the known failure modes. By definition, it cannot analyze the probability of failure modes that are not foreseen or known to the analyst. Because of this fact, history has shown us that PRAs predictably underestimate the risk unless safety factors are applied to account for the "unknown unknowns." As described in last year's Report and shown in Figure 4, the end-of-life (EOL) assessment of the Space Shuttle risk for a given launch showed that early PRAs significantly underestimated the actual risk being taken. Actual risk during early flights was as much as 10 to 100 times greater than the analyses indicated. Early Shuttle astronauts actually faced a 1 in 10 probability of catastrophe on each flight rather than the 1 in 1,000 probability that some analyses had indicated.

Because of this phenomenon, the NASA System Safety Handbook, Volume 1, System Safety Framework and Concepts for Implementation, NASA SP-2010-580, Section 3.1.1.4, calls for programs to allow a "management reserve" or margin between the PRA-calculated risk (Probability of Loss of Crew) and the maximum acceptable risk for the program (the threshold specified by the decision authority). NASA indicates that its statisticians have said that actual risk typically might be 50 percent higher than the calculated risk. Detailed information provided to the Panel revealed that for the HEOMD, including the SLS and Orion, the PRA results that are frequently compared to the Agency safety threshold requirements actually represent what the risk of those systems is expected to be when all of the heretofore unknown failure modes and design weaknesses are discovered and eliminated during actual flights and the design has matured. This approach gives a risk assessment of the "design capability" at maturity rather than a risk assessment during the early launches. Great care must be

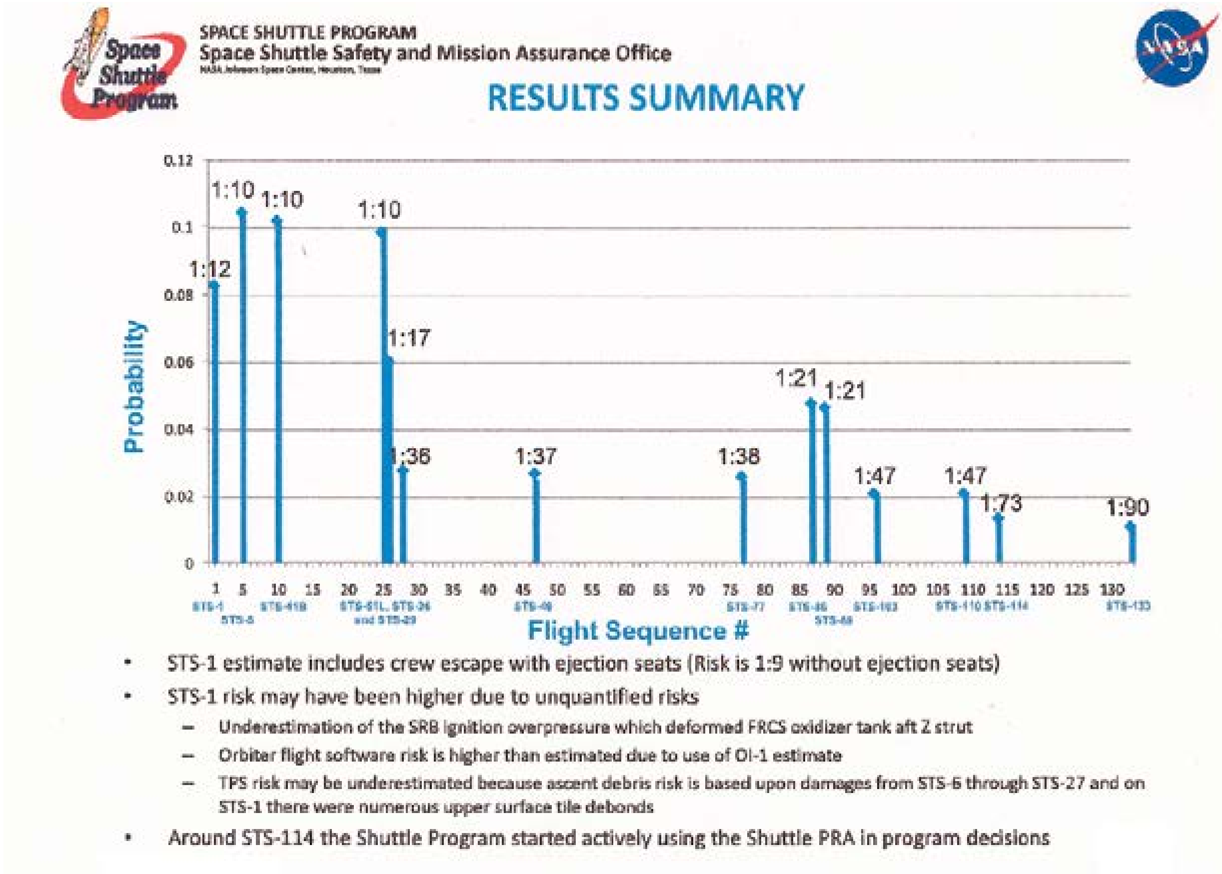


Figure 4: Results of Retrospective Analysis on Shuttle Risk.

exercised by all stakeholders to remember that actual risk for the SLS and Orion, especially during early operations, could be significantly higher than the calculated or "advertised" risk, and a healthy margin should be maintained between the PRA risk assessment calculated numbers and the minimum acceptable safety threshold. This is especially critical to remember as decisions are made concerning the first crewed flight of Orion. Current planning is considering putting crew on Exploration Mission (EM)-2, which will be the first full-up flight test of the new upper stage rocket motor as well as several critical life-support systems, including the Pressure Control System, the Air Revitalization System, and the Fire Detection and Suppression system. NASA has an extensive ground and flight test program planned to exercise these systems extensively before this flight test and to verify their design features. Included in this test program will be microgravity exposure on the ISS. However, NASA should give careful consideration to the unknowns that may be detected only by actual flight test of safety-critical Orion systems before exposing crew to the flight test regime. If NASA does indeed decide to fly crew on EM-2, the Panel urges NASA to be transparent with all stakeholders and the public on the risks involved, including the rationale supporting why crew are needed on this mission.

3. Risk Accretion

In past reports, the Panel has discussed the importance of NASA and its programs establishing thresholds for "how safe is safe enough." The ASAP was pleased to note that the NASA Exploration Systems Development (ESD) Division has now established LOC probability thresholds for its programs. The Panel was less pleased that these thresholds were not significantly safer than the actual historical performance of the Space Shuttle. It was the ASAP's hope that the inherently safer architecture of the SLS and Orion as compared to the Space Shuttle, including full abort capability, separation of energetics from the crew module, and parachute reentry instead of aerodynamic, would greatly improve inherent safety. The chosen LOC probability thresholds appear in the following table:

Flight Stage	Maximum Probability of Loss of Crew
Ascent	1 in 300
Cislunar Mission	1 in 150
Entry	1 in 300
Total Mission	1 in 75

In comparison, the mature Space Shuttle system's PRA was 1 in 90 at the end of the program for a different, but not totally dissimilar, LEO mission. It is important to note that the actual performance of the Space Shuttle over 135 flights was 1 in 67, which reflects the higher actual risk early in the program due to the unknown failure modes and design weaknesses (as noted in the previous section). This comparison is exemplified in a disturbing phrase that the Panel has heard NASA use recently: that the safety of SLS/Orion should be "no worse than Shuttle." While these thresholds represent a "worst case" beyond which NASA would terminate the Program, and the Program has established more conservative goals, the Panel is nonetheless concerned that more conservative thresholds could not be supported.

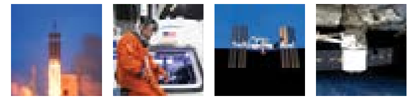
Another topic about which the ASAP is concerned that risk is not being adequately communicated is the cargo transport to the ISS under the CRS contract. The Panel has been consistently told that, given the present level of maturity of the vehicles being used by the two providers and the lack of detailed NASA insight into the programs, only "non-critical" cargo will be transported using this contract. Conversely, NASA's public statements regarding cargo flights have called the items being transferred "critical items," which gives a different impression regarding the impact that a loss of payload would have on the Program. Following the recent failure of a CRS launch, the declaration was made that while the cargo was "important," it was replaceable and no significant risk to the ISS or its crew was incurred. The ASAP commends NASA for employing risk mitigation strategies for just such a situation by spreading resupply items across the various planned launches and by not sending all of a substantive item—e.g., only 1 spacesuit of 13—on a given launch, but the Panel is not certain that all of the cargo being transported should truly be considered non-critical. Water is one item that may become a critical issue. It appears that a mixed message is being put forward as to the significance of resupply cargo being carried by the commercial providers and the risk inherent in these launches. With limited options to transport cargo to the ISS and a significant dependence on the commercial providers, formal documentation of a risk mitigation strategy would facilitate clearer communication with internal and external stakeholders. The Panel intends to explore this with NASA in the coming year.

The role of the Office of Communications (OCOMM)—commonly referred to as the Public Affairs Office (PAO)—is an important one with regard to the transparency of risk communication to external stakeholders, since it is one of the major conduits of information to the Congress, the media, and ultimately the public. The perception of external stakeholders is vitally important. If they have inaccurately perceived the level of risk and a mishap occurs, they can come to an erroneous conclusion that the mishap was caused by incompetence on the part of NASA rather than the outcome of an already identified and accepted risk. Such misapprehensions can be accentuated by OCOMM and can create perceptions that not only destroy confidence in NASA and its leadership but can lead to longer delays in the resumption of operations than may be technically indicated. This was evidenced after the Challenger mishap. By contrast, the recent response to the Orbital mishap in October 2014 modeled a response that acknowledged the difficulty and risk associated with these endeavors. OCOMM's more direct and candid approach of communicating the risk, together with the reason such risks are prudent due to the value associated with the endeavor in question, will go a long way in supporting future programs such as the Commercial Cargo and Crew programs, SLS, and the Exploration Program in general.

C. Candid Mishap Investigation and Reporting

The intent of a mishap investigation is to discover the causal factors through a comprehensive and open-minded investigation that gets to the root of the issues to prevent a repeat of the mishap. The more robust the information obtained from the investigation and delivered in the mishap report, the better the preventative measures can reduce the risk of repeating the mishap. This year, the Panel benchmarked NASA's investigation and reporting process with Naval Aviation's. The ASAP sees potential for NASA improvement in increasing mishap-reporting transparency and avoiding the potential mistake of focusing on blame rather than determining a mishap's cause for best possible risk-reduction efforts.

Only by being stringent in the practices of handling privileged witness statements and removing fear of retribution by offering privilege to the interview can the investigating authority create a condition in which the witness can be as forthcoming as possible. Similar to Naval Aviation's mishap investigation interview process, NASA's process includes a privileged status for witness statements, and per NPR 8621.1B (NASA Procedural Requirements for Mishap and Close Call Reporting, Investigating, and Recordkeeping), NASA makes a good effort to protect these statements. However, there is an exception in the NPR that allows privileged witness statements to be released to NASA's Office of Inspector General under certain conditions. It is also not clear whether NASA is required to make witnesses aware of this provision. Where Naval Aviation's and NASA's processes differ is the releasable nature of information from the NASA mishap report. To maintain the completely privileged nature of a Naval Aviation Mishap Investigation Report, a parallel Judge Advocate General Manual



(JAGMAN) investigation is conducted. Both reports are based on the same set of facts, but the JAGMAN investigation, subject to the Freedom of Information Act, is focused on accountability, while the privileged safety investigation and report is focused on root-cause discovery. This structure ensures the highest degree of forthrightness in information collection and reporting for accurate causal-factor conclusions and effective corrective actions to minimize future risks.

The releasable nature of NASA mishap reports also creates a vulnerability to focusing on blame. Generally speaking, all organizations in public view are subject to pressures of answering for errors. These pressures can lead to a focus on finding fault and assigning blame in a mishap investigation that will inherently inhibit the robustness of that investigation. Such investigations have two shortcomings: (1) filtered or less-than-transparent reporting of information and (2) the inability to discover the true root and contributing causes. The first can affect the culture of mishap investigation, because the desire to protect an individual, program, or organization in the short term hinders risk reduction in the long term. In the second case, disciplinary action associated with the resultant blame gives a false sense of confidence where it rids the organization of the problem; however, the root cause likely remains, and latent risk waits patiently for the next opportunity to strike.

The Panel will be engaging NASA in more detail on its mishap investigation process in 2015 and will continue to explore this particular issue for a better understanding of its impact on NASA's organizational culture.

D. Culture

For an organization to maximize its effectiveness and minimize risk, external and internal cultural influences should be thoroughly and constantly understood and evaluated. This general acceptance is consistent with the ASAP members' experiences. The ASAP noted that increasingly during this past year, "culture" has become a topic of interest in many parts of the Federal Government, including NASA. In 2014, NASA was recognized again as the number-one best place to work in the Federal Government for large agencies.[1] From this recognition, one could presume that all is well in the NASA culture. However, some ASAP members are concerned that all may not be "well" in the NASA culture. When the ASAP asked how NASA knows the health of its culture, particularly its safety culture, the response was not consistent across the Agency, and very few objective, measurable data are available. The data that are available are very generic and offer only a biennial snapshot of the Agency.

The ASAP considered the three major NASA accidents that have caused deaths; destruction; and considerable national, Congressional, and Presidential scrutiny: Apollo 1, Challenger, and Columbia. In reviewing the various commission reports, the "culture" theme was consistent and data-supported. In fact, in the CAIB report, culture was well highlighted. The CAIB wrote in its report: "Cultural traits and organizational practices detrimental to safety were allowed to develop," and there was

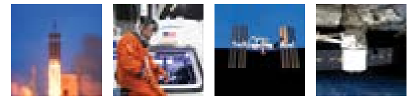
1 Rankings produced by the Partnership for Public Service.

"reliance on past success as a substitute for sound engineering practices," and there were "organizational barriers that prevented effective communication of critical safety information." The CAIB concluded that culture played a significant role in the accident. Several ASAP members began researching the impacts culture played in these accidents with a focus on what changes were made in NASA's culture to minimize or eliminate the recurrence of factors that led to these accidents. To date, the ASAP has not been able to see a process, a procedure, or an office of primary responsibility that tracks the cultural recommendations or actions resulting from these major accidents. This is not to say that the NASA culture did not or has not changed as a result of these accidents, only that there appears to be no comprehensive, Agency-wide process to implement, track, and measure these changes, particularly over the longer term, i.e., years. That said, there have been changes, and many are quite good and appear to be working. These include efforts to make changes to the Technical Authority (TA) process, safety surveys, climate assessment surveys, etc.

Culture-shaping influences come in many forms, and again, for an organization to maximize its effectiveness, the external and internal influences should be thoroughly and constantly understood and evaluated. An example for NASA is in the Agency's public release of NASA-led mishap investigation information. Because information in NASA-led investigations is subject to direct and indirect public release, the opportunity exists to soften the impact or "spin" a mishap's causes to protect an individual, group, or program. The vulnerability in the latter is especially prevalent in a fiscally constrained environment. In addition, when blame is the focus of the investigation, the true cause of a mishap can be missed or hidden, thus increasing the risk of repeating the mishap. This danger is introduced when releasable information is "spun" to appease short-term public interest. It can contribute to second- and third-order negative cultural effects in other areas such as the misinterpretation of risk and subsequent incorrect resolution, TA ambiguity, or the establishment of broad versus singular accountability for risk acceptance decisions.

Cultural influence is evident in the TA arena as well. One of the principal causes often quoted in the Columbia accident was the fact that technical personnel felt constrained or limited in bringing their concerns forward or strongly voicing their opinions, especially if those opinions were in favor of delay or postponement. TA was developed by other agencies to deal with the common conflict of objectives between technical and program personnel. Design changes cost money but improve performance; they can cause delay but improve safety. The question is: "How safe is safe enough?" In this context, TA identifies an individual who is the senior subject matter expert in an area. It becomes a requirement for the program to gain that person's agreement that the program is ready to proceed. Should that agreement be withheld, the decision to proceed must be elevated to the next most senior level and eventually, if agreement is not found, to the Administrator.

The ASAP has pursued the development of TA policy throughout the entire post-Columbia period. In late 2012 and 2013, the Panel perceived that the policy was being diluted and requested a series of briefings on the subject. In response to ASAP recommendations, NASA revised and updated the official TA policy and vetted the change with the ASAP in November 2013. This draft revision answered all of the Panel's concerns. At that time, the ASAP was told that the policy had to be coordinated through the Agency and signed before becoming



official. On that basis, the Panel turned the status of its TA recommendation from "yellow" to "green" pending signature. Finally, after more than a year, the TA policy was signed. The ASAP does not know why the signing of the policy took so long. Something in the NASA culture is causing inaction, even on policies as critical as this one. The ASAP will work with NASA to discover the cause. Mitigation of the causes for inaction or delay may contribute to an improvement in the culture that will promote more expeditious action in the future.

NASA enjoys a public reputation for being a high-quality, technically driven, professional organization. Less understood by the public is the high-risk nature of its business. NASA's culture is one of "can do" the seemingly impossible where "failure is not an option." The ASAP believes that is good and should continue and wholeheartedly applauds the proactive approach to culture improvement. However, it also believes that NASA's reputation and culture have room for improvement, e.g., NASA could determine additional ways to objectively measure its culture on a regular basis. If culture changes are needed at NASA, the ASAP would be interested in understanding the NASA change management process, measures, and outcomes. The Panel will continue supporting and working with those at NASA who are monitoring, measuring, and addressing the NASA culture.

E. International Space Station

1. Exploration Test Bed

The ISS is the centerpiece of NASA's current human space flight effort. It has provided the U.S. with a continuous crewed presence in space for over 14 years. The careful and transparent manner in which the Program has identified and corrected issues that inevitably arose has set the standard for managing such a complex space vehicle. It can teach us much on our journey to deep space exploration. NASA's capabilities-based exploration plans require the development and maturation of many new technologies and methodologies. While initial work in support of this effort will be done on Earth, it will ultimately be advantageous to do higher-fidelity development, testing, and evaluation activities in a non-terrestrial environment in order to guide decisions on the selection of systems that will provide the highest practical levels of safety, reliability, and performance. The ISS has the potential to serve as an excellent test bed for activities that require a long-term microgravity environment. A formal plan that establishes the role that the ISS will play in the support of future exploration activities would greatly enhance these activities and provide constancy of purpose for the Program. To maximize the benefits gained from Space Station operations, this plan should address how to best capture the exploration-supporting lessons now being learned from the operation and maintenance of Space Station systems, as well as identify opportunities for testing new technologies and exploring human capabilities under long-duration microgravity exposure.

2. Resupply Status

With the final Automated Transfer Vehicle (ATV) mission nearly complete (ATV-5 is currently docked to the ISS and scheduled to deorbit in February 2015) and the remaining H-II Transfer Vehicle (HTV) missions flying approximately once per year, NASA is entering a phase during which the majority of cargo necessary to sustain U.S. Orbital Segment (USOS) operations will be delivered by the CRS contractors—currently Space Exploration Technologies Corporation (SpaceX) and Orbital Sciences Corporation (Orbital). As noted in last year's Report, NASA initially based its decision to certify only the mission operations occurring within the vicinity of the ISS (i.e., within the ISS ellipsoid) on the premise that the commercial providers would fly "non-critical" cargo. The impacts of the Orbital (Orb)-3 mishap offer interesting insight into the criticality of one particular cargo item: water. With the end of ATV missions, HTV and Progress were the only other cargo vehicles certified to carry water to the ISS. NASA's plan was to have Orbital's Cygnus spacecraft certified to carry water in early 2015, but there were no plans to similarly certify the SpaceX Dragon. With Orbital missions on hold after the mishap, the ISS was left with enough water on board to last until September 2, 2015 (the crew will start using their water reserves in March 2015). The next planned water delivery capability would be the HTV mission in August 2015, leaving little margin before the September 2 deadline. The ISS program responded quickly by initiating discussions with SpaceX to have them certify their vehicle for water (targeting SpaceX CRS-6 in April/May 2015), initiating negotiations with the Russians to potentially fly water on one of their Progress vehicles, and making all efforts to return the Sabatier system on the ISS to operational status for water production. This response is viewed by the Panel as appropriate, and there is confidence that adequate water supplies will be maintained on the ISS. This particular example is meant to illustrate the importance of reliable cargo delivery services—regardless of cargo classification. In fact, the term "non-critical" can mislead and cause inappropriate perceptions leading to the conclusion that the cargo is not important, which, as shown in the water example, may not be the case. The importance of a given piece of cargo depends on a number of factors, and using or not using the term "critical" may lead to erroneous conclusions as to potential impact in the case of loss. NASA's decision to have multiple cargo providers proved to be a wise one, but both systems are still relatively immature. As noted in Part III.B of this Report, formal documentation of a risk mitigation strategy would be prudent. The ISS Program has an excellent track record for creatively solving problems, and logistics planners will need to continue emphasizing flexibility to accommodate delays or other possible mission failures.

3. Emergency ISS Deorbit Capability Development

When on-orbit construction of the ISS began in 1998, it was known by all international partners that any such large object in LEO would eventually fall back to Earth. While hundreds of other space vehicles have similarly reentered Earth's atmosphere without incident, the sheer mass of the ISS and the density of some of its components will greatly amplify the number of potentially hazardous fragments and the size of the area that they could threaten. It must be remembered that, at 357 feet in length and almost a million pounds of mass, the ISS is the largest object humans have ever placed into orbit. See Figure 5 for a size comparison.

Vehicle reentry without any inherent capability to control its reentry point was evaluated early in the Program, and the risk to personnel on the ground was deemed to be acceptable to the partners because of the low probability of fragments landing in a populated area. Since that time, additional scrutiny has been focused on the

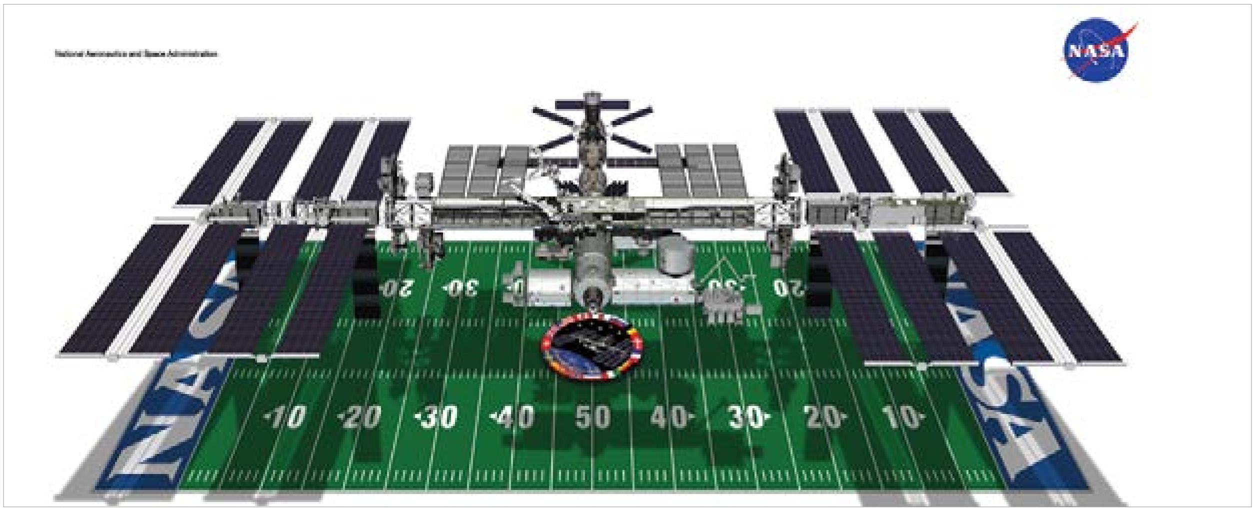


Figure 5: Space Station—the Size of an American Football Field.

risk of uncontrolled reentry of all space vehicles. New criteria have been developed for the level of risk from such events that is now acceptable to the international community. Over the past two years, NASA has worked closely with the international partners to develop procedures to more safely guide the ISS reentry when that time comes. Plans now being developed would involve sending one or more Russian Progress vehicles up to the Station and utilizing their thrusters to guide the vehicle to a safe reentry over an unpopulated area. While the planned EOL for the Space Station is a number of years in the future, it must be remembered that a serious malfunction, such as damage from a micrometeoroid or orbital debris impact or a fire, could force the evacuation of the Space Station and possibly result in loss of control. In the event of such a malfunction, recent analysis indicates that positive action would have to be taken within days to weeks of the occurrence in order to successfully control the reentry point. For this reason, the completion of comprehensive planning, including deorbit decision guidance, detailed procedures, software, and any necessary hardware modifications, is needed sooner rather than later. The Panel strongly encourages NASA to continue emphasis on working with the international partners to complete this planning as soon as possible. Their plan to use a modified reentry trajectory for an upcoming ATV flight to better understand reentry dynamics is a good example of progress in this regard.

F. Exploration Systems Development

1. Orion, Space Launch System, and Ground Systems Development and Operations

Exploration Systems Development (ESD) is making good advances. A key milestone, Exploration Flight Test (EFT)-1, was achieved with the extremely successful launch and recovery of the Orion crew module on December 5. The Panel has been tracking ESD and its three programs—Orion, the SLS, and Ground System Development and Operations (GSDO)—closely. While this system is maturing as NASA's next-generation, deep space exploration vehicle, the Panel has noted and is exploring potential risk issues.

The hardware status has been progressing quite well, with both hardware and program plans solidifying and moving from concept and initial planning to advanced planning and actual flight hardware. The Panel has noted a lot of pride and high morale at NASA facilities where ESD hardware is being produced and tested, such as Michoud Assembly Facility, Kennedy Space Center, Stennis Space Center, and Marshall Space Flight Center. Increasingly robust testing of the heat shield at cislunar reentry speeds will be conducted on EM-1 during fiscal year (FY) 2019. However, the EFT-1 test at reentry speeds above 20,000 miles per hour (mph) is most certainly an encouraging start.

The launch vehicle for the EFT-1 flight test was a Delta IV Heavy rocket. This was selected because it was recognized that the SLS booster would not be ready for an early flight test. The first SLS launch is scheduled to be EM-1 in 2018 or 2019. It includes four RS-25, Space Shuttle–derived engines and will continue development and structural testing during FY15 and FY16. Also included are two solid rocket boosters similar to those used on the Space Shuttle. Initial designs of the booster exhibited unsatisfactory propellant voids and separations that are still under investigation for complete understanding. The Panel will track this issue and is eager to see the results of the reported mitigations put in place for the firing of the second qualification motor in 2015.

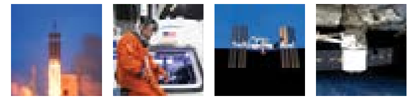
GSDO comprises several projects to handle spacecraft and rockets in addition to Orion/SLS, including Vehicle Assembly Building and launch pad modifications; command, control, communications, and range systems; and recovery systems. These are perhaps the furthest along, because they were required to support EFT-1 in December.

The Launch Abort System (LAS) on EFT-1 was flown without the actual abort motor. However, to match the expected aerodynamic and structural loads, an inert mass was used in its place and the jettison functions of the LAS were tested. The fully functional LAS has been tested with a simulated pad abort and will undergo a full flight test in late calendar year (CY) 2019 with a simulated Orion ascent abort between transonic and maximum dynamic pressure prior to the first crewed flight in FY21.

These systems are doing well individually, but the Panel has been inquiring about integrated risks of the combined three systems. The ESD program has been answering satisfactorily.

2. Future Mission Status

a. Exploration Mission-1. EM-1 will be a flight test to demonstrate critical mission events, including module separations, equipment deployments, integrated systems in-flight performance, validating environments, and integrated system performance. It will be the first flight test of the SLS core and booster stages, as well as the Interim Cryogenic Propulsion Stage for in-space maneuverability tests. Orion will fly to the vicinity of the Moon and then reenter at considerably higher speeds than EFT-1.



b. Exploration Mission-2. EM-2 is planned to be the first crewed flight and also the first operational use of the Environmental Control and Life Support System (ECLSS), which is causing the ASAP some concern. The ASAP desires to better understand the risks involved with the ECLSS and ensure that there is not a rush to conduct this mission due to constraining factors as discussed in this Report's constancy of purpose and transparency sections. This mission will most likely involve travel to a lunar orbit, then a return to Earth. This will potentially be the first operational flight of the LAS and possibly the Exploration Upper Stage, which would be different from the upper stage on EM-1. Risk on this mission is of special concern to the ASAP, as it potentially bundles a number of "new" systems together with the first crewed mission. The Panel is continuing to discuss with the Agency the plans for risk mitigation for this mission.

Figure 6: Configuration of EFT-1 and EM-1.

Figure 6 shows the hardware configuration of the EFT-1 and EM-1 missions. EM-2 will be the first crewed mission and will carry Orion, its service module, an upper stage, and the LAS. It is expected to perform a cislunar orbit and return to Earth. Missions past EM-2 have yet to be determined, but they could include the ARM or some variant. This mission would involve the entire system as expected to be configured for long-duration space missions with the exception of a habitat module—for extra crew volume—and a lander. The current ARM concept would require a spacewalk from Orion, which does not have an airlock, and this increases risk with another unknown. In order to facilitate this spacewalk, new spacesuits are currently deemed necessary because the current extravehicular activity (EVA) suits are too bulky and restrictive. These missions will continue to be the focus of future ASAP review.

3. The Road to Mars

The Panel asked the question: Where does ESD fit on the road to Mars, assuming Mars is the next major step in furthering human presence deeper into the solar system? The current thinking is that the SLS/Orion system forms the basis for the road to Mars, because it is a system that is capable of providing the underpinning for interplanetary exploration. Figure 7 depicts NASA's planning schedule for furthering human presence deeper into the solar system. Existing constraints have moved NASA to a philosophy of developing "capabilities" that

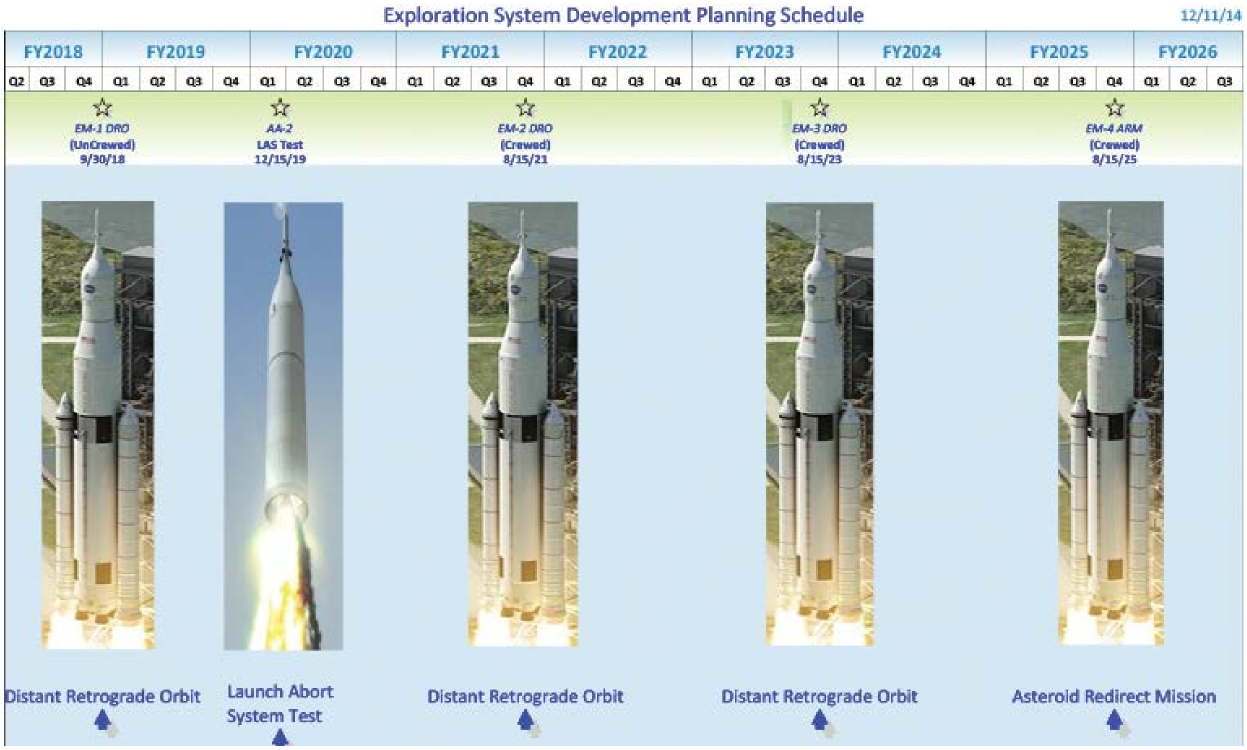


Figure 7: NASA's Planning Schedule for the Road to Mars.

are useful and necessary, regardless of the final destination that evolves. Using this rationale, developing key parts of the system becomes a goal, with a destination to be determined later.

The program currently being executed includes the ARM. It is the Agency's position that this mission is taking risk in palatable steps, and it represents a mission to a learning space currently labeled by NASA as the "Proving Ground." Here, the potential time to return to Earth increases from hours to days before leaping to a Mars-like months. While only an intermediate destination on the road to Mars or another planetary body, it does explore and provide data on an asteroid. These data, although on only one sample, may indeed become very important to Earth were an asteroid ever to be in a collision orbit. Given the funding that is likely to be available, the Panel believes it represents a reasonable approach to a mission that is achievable.

It seems reasonable, however, to ask: What else is needed? Clearly, were one to travel to and land on another planet and expect to remain for any reasonable time, there would have to be the capability to support life and provide housing. The Orion crew module by itself is not suitable for long-duration missions such as would be required for interplanetary travel. Therefore, an in-space crew habitat of some type would be required. Additionally, if we wish to land on the surface of Mars, there is also a need for a lander, surface shelter, and a wide variety of other support systems. Even if the "road to Mars" is redirected to the Moon, substantial work lies ahead in designing and building the necessary support systems.

4. Mission Risk

The risk of the en route portion of potential missions needs to be carefully considered, and the ASAP believes that a focus on this element is appropriate. In the case of the ARM, the spacecraft will be in a region of space where Earth recovery capability is on the order of days, and the crew will have to be self-sufficient for at least that duration. NASA has aptly labeled this region the Proving Ground. In addition, since Orion has no airlock for in-space egress, in order to conduct an EVA, including exploration of the asteroid itself, capsule depressurization is required and total reliance on the spacesuit for life support is necessary. Current EVA-type suits that have been used on ISS for the past many years are thought to be unworkable in the confined space of Orion and do not have the needed flexibility to maneuver. The design and development of new-design suits, while underway, are still preliminary and untested. In addition, without a habitation module, the quarters for the astronauts will have little or no room for motion or exercise. This long-duration, crew habitability risk remains to be assessed and evaluated in order to develop an objective mission risk estimate.

The ASAP and the Agency remain concerned about risks introduced in the currently scheduled frequency of SLS/Orion launches. The plan indicates a launch about every 2 to 4 years. This would challenge ground crew competency. The skills, procedures, and knowledge of conducting the launch, mission, and recovery are perishable. The ASAP believes that an extended interval requires the relearning of many lessons and skills, in contrast to Apollo and Shuttle, which had a relatively steady cadence.

In summary, the ASAP believes that the ESD program is progressing very well and is achieving significant milestones that, in addition to advancing the state of human exploration, are adding to the excellent morale of NASA employees. However, there is much more work to be done in the ESD arena with regard to defining the risks and the road to Mars. These risks should continue to be communicated openly and transparently.

G. Commercial Resupply and Commercial Crew

1. Commercial Cargo Resupply Services

In January 2014, Orbital Sciences became the second U.S. commercial provider to deliver cargo to the ISS under the CRS contract. Orbital followed with a second successful cargo mission (Orb-2) in July. SpaceX also completed two cargo missions, launching in April (SpX-3) and September (SpX-4). This increased frequency of commercial cargo missions (there were two in 2013—one Orbital demonstration flight under a Space Act Agreement and one SpaceX cargo flight under CRS) was promising given the impending end of ATV cargo missions. With the limited number of remaining HTV cargo missions flying only once per year, NASA will be dependent on the commercial cargo providers for the majority of cargo necessary to sustain USOS operations on the ISS. However, both commercial systems are still relatively immature from an operational perspective, as evidenced by a closer review of technical/schedule performance and the Orb-3 mission failure in October.

Both commercial providers have struggled to meet NASA's desired launch dates. The following table shows the initial contracted baseline launch date for each cargo mission compared to the actual launch date. Even acknowledging the fact that some missions were put on contract prior to the completion of the system development, the schedule performance must significantly improve to enable consistent scientific research on the ISS. There will be additional pressure on cargo logistics while Orbital works through its plan to resume cargo missions. NASA's logistics planning and adjustments during this critical period will be a focus for the Panel in the coming months.

Flight	Original Baseline Launch Date	Actual Launch Date	Overall Delay	Contractor Delay	NASA Delay
SpX-1	12/2010	10/2012	22 months	22 months	0
SpX-2	07/2011	03/2013	20 months	20 months	0
Orb-1	10/2011	01/2014	26 months	25 months	1 month
SpX-3	01/2012	04/2014	26 months	26 months	0
Orb-2	06/2012	07/2014	25 months	24 months	1 month
SpX-4	06/2012	09/2014	27 months	22 months	5 months
Orb-3	06/2013	10/2014	16 months	15 months	1 month

Both commercial providers have also faced technical challenges during the missions. Some of the early SpaceX missions under the CRS contract experienced water intrusion after landing and loss of power to returning science payloads. Additionally, SpaceX successfully overcame a Falcon 9 engine failure during ascent on SpX-1 and, with NASA's help, a significant thruster issue on SpX-2. Orbital's two missions preceding the loss of the Orb-3 vehicle had no significant anomalies. Again, the Panel believes that the demonstrated performance is indicative of the operational maturity of the systems. It is important that both SpaceX and Orbital show improved reliability as they gain mission experience to increase NASA's confidence in this strategy to use and rely upon commercial providers.

The loss of the Orb-3 vehicle in the first seconds of ascent (Figure 8) was a setback for Orbital and NASA. This mishap will have short-term impacts to logistics as noted in the ISS section and potentially some long-term impacts depending on how quickly Orbital resumes cargo missions and on how SpaceX performs during the period when it is the only operational commercial cargo provider. Orbital recently announced its intention to launch its Cygnus spacecraft on an alternate launch vehicle to minimize the downtime between the mishap and

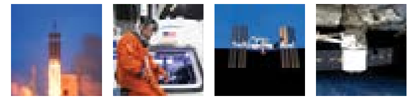


Figure 8: Orb-3 Launch Mishap.

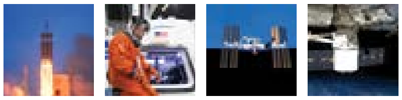
its next cargo mission. The Panel supports the strategy of resuming Orbital cargo flights as quickly and as safely as possible while the mishap investigation on the Antares launch vehicle can proceed independently.

Overall, the challenges faced by the commercial cargo providers are not unexpected. Both Orbital and SpaceX are working to improve reliability and schedule performance. NASA oversight and certification of mission operations in the ISS ellipsoid have proven effective. With the CRS contract administered under the ISS Program, there has been transparency, the acknowledgement of challenges, and a positive safety culture. Additionally, the Panel noted that the recently released Request for Proposal for the next contract (CRS2) incorporated significant lessons learned by NASA.

2. Commercial Crew Program (CCP)

In terms of executing its acquisition strategy, 2014 has been a very successful year for the CCP. Phase 1 of the acquisition, the Certification Products Contract (CPC), was completed in June. NASA completed the source selection process for phase 2, the Commercial Crew Transportation Capabilities Contract (CCtCap), in September with awards of two contracts to Boeing and SpaceX. Despite a protest, both companies have started work under those contracts. Work under the Commercial Crew Integration Capabilities (CCiCap) Space Act Agreements (SAAs) continues for SpaceX and Sierra Nevada Corporation, with a few significant milestones still remaining. Boeing's CCiCap SAA was completed on schedule.

The Panel strongly supports NASA's decision to select two companies for the CCtCap contract. First, having two companies on contract increases the likelihood that at least one crew transportation system will achieve NASA certification by 2017. When both systems are certified for crew missions, NASA will benefit from competition for ISS services missions. Also, the inherent dissimilar redundancy of these two systems means that



a technical issue with one system will not preclude continued U.S. access to the ISS.

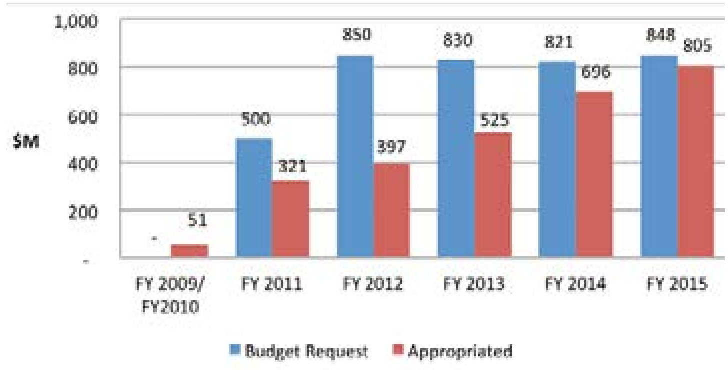
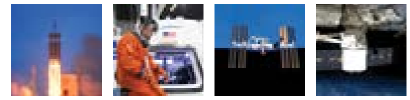


Figure 9: CCP Funding.

The NASA Administrator has stated publicly that the Program needs the full budget request in future years to fund both CCtCap contracts. Based on previous appropriations (Figure 9), the Panel is concerned that the Program may not be sufficiently funded to meet its contractual obligations. Under these Firm Fixed Price (FFP) contracts, the contractor receives pre-determined payments for the completion of pre-defined work (milestones). If the Program does not receive sufficient funding, the contractor cannot be directed to "slow down" without an equitable adjustment (increase) in the fixed price. Alternatively, reducing the scope of certification work to accommodate funding shortfalls could affect safety. The Panel does, however, positively recognize the trend of increasing appropriations in FY12 through FY15 and strongly encourages Congress in future years to appropriate the dollars necessary for NASA to fully fund the two CCtCap contracts.

Even with sufficient funding, there are significant challenges to developing and certifying complex, one-of-a-kind systems under FFP contracts. These challenges were detailed in last year's Report, and NASA has attempted to address some of those challenges with the CPC phase of the acquisition strategy. Under CPC, NASA was supposed to approve each contractor's Certification Plan, Verification and Validation Plan (including variances), Hazard Reports, and Alternate Standards prior to entering into the CCtCap FFP contracts. Despite the fact that these four products were CPC deliverables (paid for by the taxpayer) and circulated within the NASA technical community (with appropriate proprietary markings), the ASAP was not given access to these products or NASA's evaluation and disposition (approval/disapproval) during the CPC period of performance. This lack of transparency has continued under the CCtCap contracts. With a protest in place, the Panel is sensitive to protecting the actual proposals. However, work is proceeding, and the Panel has been denied access to critical safety and certification information contained in the initial contract deliverables. The lack of transparency within the Commercial Spaceflight Development Division at NASA Headquarters is very troubling to the Panel. Just prior to the release of this year's Report, NASA finally provided the Panel with the CPC products mentioned above (7 months after the contracts were concluded). Examination of these products will take considerable effort, and this work will be the focus of the first ASAP meeting in 2015. However, at the current time, without a detailed examination of the certification products for each system, the Panel is unable to make any proactive safety assessments or recommendations concerning the CCP certification process.



IV. Conclusion

The ASAP salutes NASA on the many accomplishments achieved during 2014. Among many others, these include safe International Space Station (ISS) operations, growing traction on the Exploration Systems Development (ESD) program, success in supporting ISS logistics via commercial cargo, and positive strides in infrastructure management. The leadership and program management of the ISS are highlighted for their openness, transparency, and candor. The ISS culture is a space flight exemplar.

The Panel's observations and top concerns include budget and constancy of purpose, transparency, and risk management.

NASA's budget is insufficient to deliver all current undertakings with acceptable programmatic risk. History clearly shows that programmatic risk precipitates tradeoffs that are not in support of good safety practice. The Panel highlights three possible methods to relieve this situation: (1) prioritize and set aside programs, activities, and infrastructure of lesser import (i.e., do fewer things better); (2) improve the utility of NASA's investment by completing programs of record versus the restarts that too often follow Administration change (i.e., finish what is started); and (3) form a lasting consensus among the Administration, the Congress, and NASA on a genuine, long-term mission and vision and provide the funding required to deliver it.

In the face of today's funding shortfalls, NASA has embraced a strategy of "capabilities-based" investments. This strategy develops and matures many of the new technologies and methodologies required for the future but does not deliver an integrated capability. While this is an understandable pragmatic response to insufficient funding, this approach costs more in the long run.

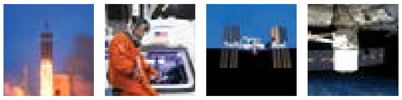
While generally pleased by NASA's transparency and candor, as evidenced by the leadership of the ISS Program Manager, the ASAP finds the Commercial Crew Program (CCP) to be an exception. The Director of Commercial Spaceflight Development has maintained a seamless set of constraints to transparency and communication since program initiation. *This leaves the Panel unable to offer any informed opinion regarding the adequacy of the certification process or the sufficiency of safety in the CCP.* We are concerned that this failure to communicate is reminiscent of the cultural problems that were explicitly identified by both the Rogers Commission and the Columbia Accident Investigation Board.

With respect to risk, the Panel again poses the question "How safe is safe enough?" and notes that the ESD program Loss of Crew thresholds are not significantly safer than the Space Shuttle's performance at maturity. The Panel notes that NASA needs to do a better job of communicating the risk inherent in human space flight. The way the Agency communicated the danger Curiosity faced in landing on Mars is a good role model.

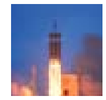
Appendix A:

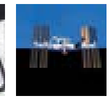
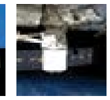
Summary and Status of Aerospace Safety Advisory Panel (ASAP) Open Recommendations



2014 Recommendations		
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. Follow on action: NASA should adopt the process as briefed on part (2) of the recommendation.
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. Pending NASA implementing a policy that formally incorporates appropriate policies and technical standards of those lessons that are most important to safety and mission success. Next update expected in early 2015.
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. There remains a reluctance and/or a delay in implementation of a single signature risk acceptance process during development. Currently, risk is often accepted collectively by committees and panels and documented in their minutes without assigning specific leadership accountability. A draft response proposing a policy change to direct single signature risk acceptance was shared with the ASAP. This is the direction ASAP has recommended. When that response is signed, this recommendation will turn yellow and the recommendation will close upon completion of the proposed policy update.

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 or issue, but one that is currently 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.



Open Recommendations from Prior Years		
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. Awaiting completion of timeline for the detailed planning AND software for controlled ISS deorbit, in both the planned and unplanned conditions.
2012-03-01	**Software Assurance and CMMI Requirements:** All NASA internal safety-critical software development groups should achieve CMMI Level 3 (or an equivalent as established by external validation agent) by the end of FY14.	▲ OPEN. Pending completion of CCMI ML 3 at KSC expected in Spring 2015. ASAP changed status to yellow in July 2014 due to consistent schedule slip.
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 MIT and the investigation Board Chairs in greater detail to include the method, consistency, and quality of training for MIT members and Board Chairs.	● OPEN. Awaiting development and implementation of safety investigation training program with planned completion in FY15.

Appendix B:

Closure Rationale for Recommendations Closed in 2014

2012-04-01

Alignment of Technical Authorities' Budgets with Line Authority: NASA should review and determine the appropriateness of having the technical authorities—OSMA, OCHMO, and OCE—in a non-safety-aligned budget line item and office.

Closure Rationale
The technical authorities budget in NASA is called Safety and Mission Success (SMS) and falls under the appropriations line item called Cross Agency Support (CAS). The ASAP was concerned that the line item for CAS could be cut without understanding the impact to safety. In FY15 budget, the line item was changed from CAS to Safety, Security and Mission Services (SSMS).

2013-01-01

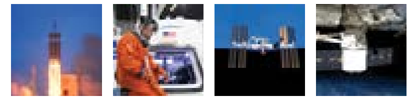
Philosophy on the Certification Process: NASA should develop a philosophical approach to the certification process; specifically, when NASA certification is required and when it is not.

Closure Rationale
NASA has provided an acceptable response on CCP approach. The ASAP understands there is no current plan for NASA to fly personnel on Flight Opportunities Programs. If NASA decide to fly personnel on Flight Opportunities Programs, then ASAP would like to hear about certification approach for those missions in advance of the decision to fly.

2013-03-01

Technical Authority (TA) and Role of Center Director: (a) Revise NPD 1000.0A, NASA Governance and Strategic Management Handbook, to reflect the Administrator's current governance model and specifically address the question about how non-concurrences are handled. (b) Make a clear distinction in the TA policy between the formal appeal process related to TA decisions and the dissent process related to non-authoritative differences of opinion on matters outside the TA's authority.

Closure Rationale
NPD 1000.0A, NASA Governance and Strategic Management Handbook was revised on November 26, 2014, to reflect the Administrator's current governance model and specifically address the question about how non-concurrences are handled and added clarity on the TA appeal process.



2013-03-02

Firm Loss of Crew (LOC) Number for the Exploration System Development (ESD) Program: Establish a firm, Agency-level safety threshold and goal for LOC for ESD's first crewed mission as soon as possible.

Closure Rationale
NASA provided a copy of the signed decision memorandum that documents the Administrator's approval on Agency-level safety thresholds for crew for human cislunar missions to ASAP.

2014-AR-01

Definition of Missions, Objectives, and Requirements for Performance and Certification: NASA should clearly define missions, objectives, and requirements—for both performance and certification—in a timely manner. Once they are defined, NASA should resist continually changing these elements because of the deleterious impact on cost, schedule, performance, and safety.

Closure Rationale
NASA response dated July 22, 2014. Current capabilities approach and budget realities do not currently support a definitive requirement statement. ASAP shall continue to monitor.

2014-AR-02

Identification and Communication of Safety Risk: NASA should rigorously identify the risks that it is accepting and the rationale for accepting them—i.e., the value expected that justifies accepting a safety risk—and transparently communicate this information to NASA's stakeholders and the public.

Closure Rationale
NASA briefed the ASAP on their decision process for cislunar LOC/LOM threshold and goal.

2014-AR-03

Competition in the Commercial Crew Program: In a fixed-price environment, NASA should maintain competition in the CCP until there is confidence that the acceptable level of safety will be achieved.

Closure Rationale
NASA selected Boeing and Space X for CCtCap on September 16, 2014, maintaining competition on the Commercial Crew Program.

2014-AR-04

Realism in Cost and Schedule: NASA should strive for realism in cost and schedule.

Closure Rationale
NASA response dated July 22, 2014. Current capabilities approach and budget realities do not currently support developmental, development or life cycle cost estimation. ASAP shall continue to monitor.

2014-AR-06

Commercial Cargo Risk Policy: NASA should revisit its Agency-level commercial cargo risk policy.

Closure Rationale
NASA response dated July 22, 2014.

2014-AR-07

Robust Safety Culture: NASA should continue to foster a robust safety culture.

Closure Rationale
NASA response dated July 22, 2014. ASAP believes that safety culture is important and the Agency should continue to keep this a priority. ASAP will continue to monitor this topic.

Aerospace Safety Advisory Panel

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Captain Robert E. Conway, USN (Ret.)
Mr. John C. Frost
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