



AEROSPACE SAFETY ADVISORY PANEL

ANNUAL REPORT
for 2019



NASA AEROSPACE SAFETY ADVISORY PANEL

National Aeronautics and Space Administration
Washington, DC 20546
Dr. Patricia Sanders, Chair

January 1, 2020

The Honorable Jim Bridenstine
Administrator
National Aeronautics and Space Administration
Washington, DC 20546

Dear Mr. Bridenstine:

Pursuant to Section 106(b) of the National Aeronautics and Space Administration Authorization Act 2005 (P.L. 109-155), the Aerospace Safety Advisory Panel (ASAP) is pleased to submit the ASAP Annual Report for 2019 to the U.S. Congress and to the Administrator of the National Aeronautics and Space Administration (NASA). The Report is based on the Panel's 2019 fact-finding and insight visits; quarterly public meetings; direct observations of NASA operations and decision-making; discussions with NASA management, employees, and contractors; and the Panel members' past experiences.

The Panel noted considerable headway toward NASA's human exploration objectives this year. We are supportive of the significant amount of testing—both completed and underway—as well as the thoroughness of ongoing work to resolve technical issues. While many challenges remain, the progress to date is encouraging; however, much work lies ahead. This is a time for both excitement and reasoned caution.

NASA's human space flight brand and reputation are driven by 60 years of operational excellence performing complex missions in extraordinarily difficult endeavors. Nevertheless, the dynamic environment of Lunar 2024, imposed on an Agency still involved in complex and hazardous operations in orbit, while simultaneously developing or sponsoring development of new rockets, spacecraft, and critical equipment, will challenge the NASA community. As the Agency undertakes the most ambitious human foray beyond Low Earth Orbit (LEO) since 1972, we advise:

- Regardless of how NASA addresses the technical challenges, the nation must avoid fluctuating policy goals, ambiguous objectives, budget inadequacies, and instability—including partial and full-year Continuing Resolutions—which add complexity and uncertainty to program management.
- Acknowledging the value of setting challenging but realistic and achievable schedules, NASA must guard against undue schedule pressure that might lead to decisions adversely impacting safety and mission assurance.
- NASA leadership must deliberately focus on communication and engagement with the workforce to preclude disconnects in risk assumptions across the organization and a culture of risk *taking* rather than one focused on deliberate risk *management*.
- As NASA evolves its interactions with commercial providers, it must maintain focus on the core tenets of system development as the mission is ultimately still a NASA responsibility.

The ASAP made two formal recommendations this year: one addressed the Safety and Mission Assurance Technical Excellence Program (STEP) training, and the other dealt with development and transition to Next Generation Extravehicular Mobility Units (EMUs). These recommendations, as well as ASAP recommendations from prior years, will be discussed in this report. One longstanding recommendation concerning human space flight mishap response has risen in urgency and will also be addressed.

I submit the ASAP Annual Report for 2019 with respect and appreciation.

Sincerely,



Dr. Patricia Sanders
Chair, Aerospace Safety Advisory Panel

Enclosure

NASA AEROSPACE SAFETY ADVISORY PANEL

National Aeronautics and Space Administration

Washington, DC 20546

Dr. Patricia Sanders, Chair

January 1, 2020

The Honorable Michael R. Pence
President of the Senate
Washington, DC 20510

Dear Mr. President:

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National Aeronautics and Space Administration
Washington, DC 20546
Dr. Patricia Sanders, Chair

January 1, 2020

The Honorable Nancy Pelosi
Speaker of the House of Representatives
Washington, DC 20510

Dear Madam Speaker:

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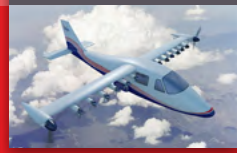
Dr. Patricia Sanders
Chair, Aerospace Safety Advisory Panel

Enclosure



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The ASAP Charter and Quarterly Meeting Minutes can be found at <https://oiiir.hq.nasa.gov/asap/>



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.

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. The closure rationale for recommendations closed in 2019 is summarized in Appendix B. The Panel’s issues, concerns, and recommendations are based upon the ASAP fact-finding and quarterly public meetings; insight visits and meetings; direct observations of NASA operations and decision-making; discussions with NASA management, employees, and contractors; and the Panel members’ expertise.



I. Introduction and Overview

A. Overview of Aerospace Safety Advisory Panel 2019 Activities and Program of Work

During 2019, the Aerospace Safety Advisory Panel (ASAP or Panel) conducted quarterly meetings hosted by Kennedy Space Center (KSC), Marshall Space Flight Center (MSFC), NASA Headquarters, and Johnson Space Center (JSC). In addition, ASAP members made insight visits to the NASA Safety Center (NSC) and several of NASA's industry providers and engaged in discussions with NASA Engineering and Safety Center (NESC) personnel. Two members of the Panel participated in the Inter-center Aircraft Operations Panel (IAOP). The ASAP and the NASA Advisory Council continue to include representative participation in each other's meetings in order to facilitate broader perception and understanding of issues across NASA.

The Panel's attention this year remained focused on the qualification testing, analysis, and validation efforts of the Commercial Crew Program (CCP) and the Exploration Systems Development (ESD) as both efforts move closer to launch of uncrewed flights and crewed flights, as well as operational status. With the announcement by the Administration of the intent to return United States astronauts to the Moon by 2024, we placed increased focus on the plans under development for lunar and deep space explorations. NASA is intensely engaged in multiple simultaneous and complex activities, with significant events occurring even as this report is being written. The Panel's intent is to provide advice targeted to drive down risk to the lowest possible level consistent with accomplishing the mission. Space exploration is inherently hazardous. The environment is hostile, and the systems needed to operate and survive in it are complex. Our charge is not to avoid risk at all costs, but to manage risk intelligently.

The Panel noted considerable headway toward NASA's human exploration objectives this year. We are supportive of the significant amount of testing—both completed and underway—as well as the thoroughness of ongoing work to resolve technical issues, much of which will be highlighted in this report. While many challenges remain, the progress to date is encouraging; however, much work lies ahead. This is a time for excitement and optimism as well as reasoned caution.

The ASAP made two formal recommendations this year: one addressed the Safety and Mission Assurance Technical Excellence Program (STEP) training, and the other dealt with development and transition to Next Generation Extravehicular Mobility Units (EMUs). These, as well as ASAP recommendations from prior years, will be discussed in subsequent sections of this report. One longstanding recommendation concerning human space flight mishap response has risen in urgency and will be commented on later in this introduction.



B. Resources

A recurring theme for the Panel is Constancy of Purpose—the requirement for a steadfast national commitment to pursue articulated human space exploration goals that do not waver over time, along with a willingness to support those goals with the necessary resources. Regardless of how NASA addresses the technical challenges, fluctuating policy goals, ambiguous objectives, budget inadequacies, and instability—including partial and full-year Continuing Resolutions—add complexity and uncertainty to program management. The result is inefficiency in program execution, detracting from the ability to achieve the technical goals with the requisite focus on safety and mission assurance. The consequence of the nation and government not sustaining a clear and constant commitment to articulated goals and objectives is a program beset with constant resets, associated delays in achieving any goals whatsoever, extended schedules, and, inevitably, increased risk.

NASA's Continuing Resolution (CR) History—Fiscal Year (FY) 2008–2020 (as of 12/23/2019)											
	CR-1	CR-2	CR-3	CR-4	CR-5	CR-6	CR-7	CR-8	Final Appropriations	Date Enacted	Months Under CR
FY 2008	PL 110-92	PL 110-116	PL 110-137	PL 110-149					PL 110-161	12/26/07	3
FY 2009	PL 110-329	PL 111-6							PL 111-8	03/11/09	6
FY 2010	PL 111-68	PL 111-88							PL 111-117	12/16/09	3
FY 2011	PL 111-242	PL 111-290	PL 111-317	PL 111-322	PL 112-4	PL 112-6	PL 112-8	PL 112-10	PL 112-10	04/15/11	12
FY 2012	PL 112-33	PL 112-36	PL 112-55	PL 112-67	PL 112-68				PL 112-55	11/18/11	2
FY 2013	PL 112-75								PL 113-6	03/26/13	6
FY 2014	PL 113-44	PL 113-67	PL 113-73						PL 113-76	01/17/14	4
FY 2015	PL 113-164	PL 113-202	PL 113-203						PL 113-235	12/16/14	3
FY 2016	PL 114-53	PL 114-96	PL 114-100						PL 114-113	12/18/15	3
FY 2017	PL 114-223	PL 114-254	PL 115-30						PL 115-31	05/05/17	7
FY 2018	PL 115-56	PL 115-90	PL 115-96	PL 115-120	PL 115-123				PL 115-141	3/23/18	6
FY 2019	PL 115-245	PL 115-298*	PL 116-5						PL 116-6	2/15/19	5
FY 2020	PL 116-59	PL 116-69							**	12/20/19	2

FIGURE 1. The history of CR usage shows constant budget uncertainty over many years.

* Lapse in appropriations for all government agencies (including NASA) without a full-year appropriation, from 12/12/18 through 1/25/19.

** Public Law number not been assigned as of 12/23/19.



The three-legged stool of developmental program management—cost, schedule, performance—remains fundamental for successful program execution. If NASA is to achieve the expected performance, including mission assurance and safety, and reach the desired goals within reasonable timelines, the requisite resources must be made available. Along with the requisite resources, the Agency must be provided with the necessary stability in order to plan and manage a feasible program of work. The history of resource ambiguity resulting from year after year of Continuing Resolutions, illustrated in **Figure 1**, adds complexity to program management and inefficiency to execution, while creating a potential distraction from safety and mission assurance.

C. The Schedule Challenge

The Panel continues to advise NASA leadership to closely monitor the impact of schedule perturbations on the workforce. While the ASAP acknowledges the importance of setting challenging but realistic and achievable schedules, we caution not to allow undue schedule pressure to lead to decisions that adversely impact safety and mission assurance. The declaration earlier this year that NASA astronauts will return to the Moon in five short years has added a vibrant urgency to an already complex and ambitious endeavor.

As NASA prepares to meet this aggressive yet exciting goal, while simultaneously continuing the CCP and operations on the International Space Station (ISS), our Panel continues to advise caution and diligence. Setting an ambitious goal is exciting and can be highly motivating. It also can be detrimental to employee morale if a clear path toward realization in the timeframe articulated is not provided to the workforce. An aggressive schedule, backed by a realistic plan, can provide a foundation for achieving greater decision velocity, restructured and more efficient workflow, and more streamlined overall approaches. But targeted launch dates not backed by realistic and well-thought-out planning can result in poor decisions, at least from a safety perspective, if the race to meet arbitrary deadlines results in imprudent shortcuts or the elimination of important testing.

In working toward Commercial Crew launches as well as the Artemis-1 and -2 test flights, it is important for NASA to recognize that several critical data sets are required to quantify the risk, understand operating margins, and ensure the optimal safety of human flight. For example, documented data on the margins resulting from structural, thermal, acoustical, and propulsion testing, as well as integrated performance of critical systems such as the heat shield, parachutes, abort mechanisms, and the Environmental Control and Life Support System (ECLSS), must be well understood before launching a new vehicle into space with humans on board.

D. Workforce

NASA's human space flight brand and reputation are driven by 60 years of operational excellence performing complex missions as part of an extraordinarily difficult endeavor. The Agency is known for



methodical, highly reliable decision-making and management processes in preparation for and while executing missions. Further, NASA has been able to achieve one challenging goal after another even while constrained and impacted by the changing dynamics that face government organizations. The foundation of this legacy has always been NASA's combined civil service and contractor workforce, who conduct the engineering, maintenance, and operations of all NASA's missions, and their incredible ability to make such difficult and hazardous work so successful that it often looks easy.

In addition to an impressive list of achievements over the last decade, there has been considerable change in the human space flight strategy, and NASA's exploration tasks have been a "moving target" across Administrations. As the Panel has pointed out in previous reports, serial changes in direction and strategy can have a destabilizing effect on the workforce and lead to a lack of clarity in communication, a disconnect in risk assumptions across the organization, and, at worst, a culture of risk-taking rather than one focused on deliberate risk *management*.

The dynamic environment of Lunar 2024 imposed on an Agency that is still involved in complex and hazardous operations in orbit (ISS) while simultaneously developing or sponsoring the development of new rockets, spacecraft, and critical equipment will stress the NASA community. The cumulative effect of these changes on the workforce has the potential to impact risk management across the Agency. As the Panel has pointed out before, one of NASA's strengths is the unwillingness to give up when faced with a tough challenge; this strength could become a weakness if a management team establishes an unrealistic program that contains time and budget constraints without fully addressing and managing risks.

We advise NASA leadership to deliberately focus on transparency and engagement consisting of candid discussions at and between all levels of management around questions such as these:

- What is the strategy and what are the impediments and concerns from the top down?
- What are the corresponding concerns from the bottom up?
- What is the management team evaluation and response to the bottom-up concerns?
- What are the ongoing processes to periodically "take the pulse" on all of the above and consider course corrections?
- Through what regular management- and workforce-engagement process is NASA confident that it is appropriately managing risk, not simply taking risk to meet objectives?

NASA senior management continues to espouse a commitment to safety and mission assurance and to "not fly until ready" and has acted consistently with that philosophy to date. At the same time, there is a sense that there is also a commitment to achieving goals "no matter what." There is a danger that NASA's internal transparency and critical risk management culture could erode as the Agency undertakes the most ambitious human foray beyond Low-Earth Orbit (LEO) since 1972. Senior management may be determined to make the prudent decisions, but there are a multitude of lower-level judgments made daily throughout the workforce that impact safety and mission success. We



advise vigilance in maintaining awareness across all organizational levels of the consequences of actions and decisions. Recurring and open discussions around the themes articulated above will have the combined effect of focusing the current execution and reinforcing trust at all levels and will reinforce the deliberate risk management culture upon which NASA's greatest achievements have always relied.

E. Moving Forward

The Panel continues to recognize that while NASA should never lose sight of the fundamentals of risk management for successful program execution, there is no single approach that dictates how to understand and control margins. As NASA continues to alter how it interacts with industry, it will be necessary to be open to alternative means. However, it is also vital that the core tenets of system development be maintained: identifying the performance margins of the system, understanding those margins, and controlling the operational environment in which those margins are documented. These core tenets should apply regardless of the methodology used. There are two specific areas to which the Panel calls attention.

First, as NASA broadens the human space flight program to cislunar exploration, the Agency will need to expand on the lessons learned from the experiences of the CCP. What worked well? What didn't meet expectations and why? We will say more about this later in this report. But as NASA evolves its partnering relationships with commercial providers, the Agency should not lose sight of the fact that the mission is ultimately still a NASA responsibility. In other words, NASA still retains accountability for mission assurance, human flight certification, and safety and must play a leadership role among all enterprise partners.

Second, as NASA's human exploration of deep space reaches beyond LEO to the Moon, and eventually Mars, risk management will become more complex. Leaving the near-Earth environment and embarking on longer transit timelines, without quick emergency return options, increases the exposure to risks and, therefore, the necessity for a robust mix of highly reliable and fault-resistant designs. NASA's science missions have a history of dealing with extremely long-range operations, but human space flight imposes even greater complexity and demands an elevated level of confidence in performance. Traditional approaches to achieving very high levels of assurance may need to be reexamined. Some efforts have already begun. For example, we have already seen some movement away from component redundancy—with its weight penalty—toward a dependence on higher reliability in critical elements, as in the case of the Orion service module propulsion system. Such decisions, and potential shifts in design philosophy, will no doubt be necessary but must be made with deliberate, detailed, and important dialog on the risk trade-offs for the overall program, again adhering to the core tenet: reaching full understanding of the design margins, a comprehensive strategy for operating within those margins, and clear articulation of the rationale for the decision.



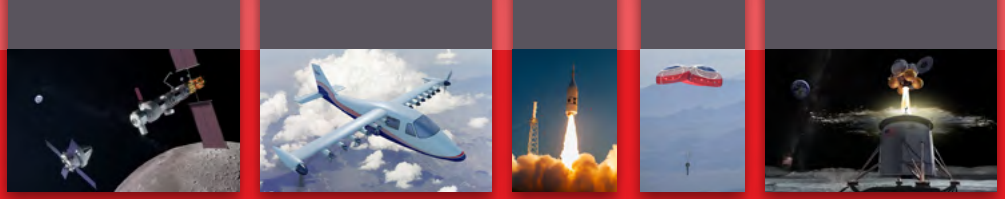
F. Open and Future Work

We must continue to recognize that space flight holds inherent hazards and always carries the possibility for mishaps regardless of how carefully risks are managed. Therefore, in the event of a mishap, it is prudent to have mechanisms and procedures in place for rigorous and disciplined investigation that not only can recommend corrective action, maximize learning, and avoid future incidents, but also can ensure a return to flight as safely and as soon as possible after an incident. NASA has internally documented such procedures, but the NASA Authorization Act of 2005 also requires a Presidential Commission for Human Space Flight Independent Investigation if an accident occurs. In 2015, the ASAP, concerned with several provisions of that Act, recommended that the language be reviewed and revised in light of today's systems and environment. This recommendation remains open even as the need has become increasingly urgent. NASA will soon resume human space flight operations, and it is imperative that the appropriate procedures for investigating any mishap involving loss of life or high-value assets be in place before that time. The Panel has previously provided details on its concerns with the provisions of the Authorization Act and suggested alternatives.

Another persistent concern of the Panel is the risk of damage to orbiting spacecraft due to micro-meteoroids and orbital debris (MMOD). The hazard from MMOD has been recognized as a major issue in every program. MMOD is the dominant contributor to the calculations of loss-of-crew (LOC) predictions for both commercial crew vehicles and Orion, and it is a factor in two of the top three safety risks for the ISS. We were encouraged that Space Policy Directive-3 focused on this risk, but it remains essential that meaningful implementation actions be taken to address what is a burgeoning safety hazard. Given the increasing congestion in orbit and industry-wide plans to launch many mega-constellations in LEO, consisting of hundreds or even thousands of satellites, this issue needs immediate attention.

An emerging area of concern for the Panel is an increase in issues with the vendor supply chain and apparent deterioration of the quality of that base. There have been notable instances where (1) the dependence on a single available vendor has caused programmatic and/or technical issues or (2) a previously respected provider of high-quality components has supplied inferior products. Both circumstances are disturbing and may indicate a serious trend. We do not have a recommendation at this time, but we advise vigilance with respect to supply chain management and parts qualification.

In the coming year, the ASAP plans to focus its efforts on the culmination of the CCP's certification efforts and to continue its examination of the significant test events leading up to the Artemis-1 and -2 missions. In addition, we will expand engagement with the components of lunar and deep space exploration efforts. The Panel intends to direct attention toward some aspects of NASA's aircraft operations, as will be discussed later in this report. And as part of our program of work, we will continue to gain understanding of the overall safety culture environment at NASA by observing the safety audit process in action.



II. International Space Station

A. Overview

Two thousand nineteen marks the 19th year of continuous human presence in LEO aboard the ISS. Thus far, over 2,800 investigations have been completed on the ISS by over 3,800 investigators from 107 countries. Over 1,768 scientific publications have resulted from ISS research. Of particular interest to the Panel this year is the LambdaVision project, leveraging the microgravity environment of the ISS in the development of high-resolution, protein-based artificial retinal implants. The goal is to restore vision in patients with degenerative diseases such as retinitis pigmentosa and age-related macular degeneration. These experiments have potential for implementation of a significant clinical advance in ophthalmology. This and other ISS projects demonstrate the potential value of ISS research to life on Earth.

The ISS Program is an outstanding technical achievement and establishes a model of international cooperation on which future human space flight programs can be based. The leaders and involved members of each space agency have been able to sustain cooperation through the years of continuous operation, despite changes of key personnel at all levels. This tradition of mutual trust and excellence continues today.

B. Exploration Risk Mitigation

The ISS remains an invaluable asset for understanding the complexities of living in space, including the ability to develop and test technology in microgravity and to perform research. It serves as a testbed to study the physiological impacts of long-term space flight on humans and to evaluate performance of key future spacecraft system components. Both of these areas of research and development are helping to buy down risk for future missions beyond LEO. Two particular examples illustrate the research importance of the ISS for current and future space flight missions:

1. The ISS has allowed NASA to test critical Orion capsule ECLSS components (for instance, the Phase Change Module/wax sublimator) on-orbit. The results of those tests have informed design refinements to be accomplished well before the assembly of what will ultimately become the EM-2/Artemis-2 spacecraft.
2. The ISS has enabled the development of a more in-depth understanding of the physiological impacts of long-duration space flight, primarily through the observation and study of multiple aspects of human health with ever-increasing space flight duration.

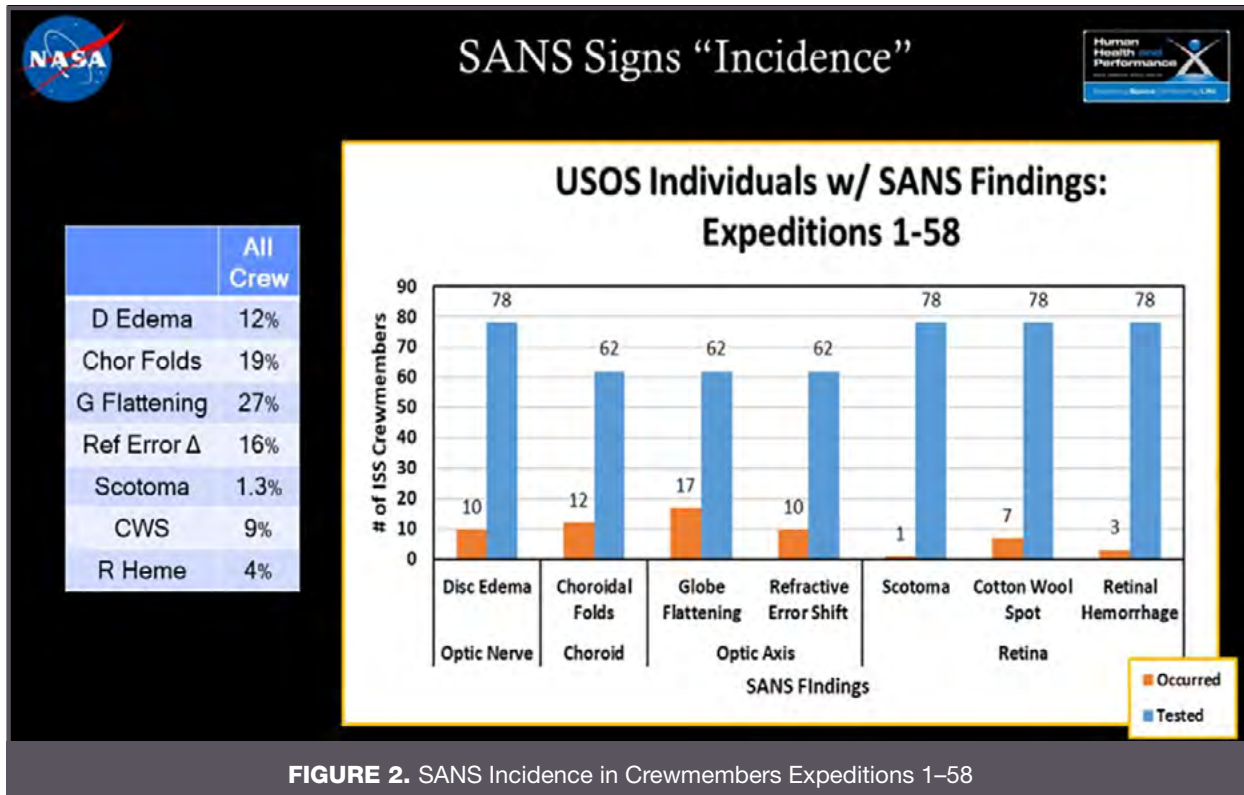


FIGURE 2. SANS Incidence in Crewmembers Expeditions 1–58

The health risks of human space flight, NASA’s efforts to mitigate those risks, and the activities of the Health and Medical Technical Authority (HMTA) are of ongoing interest to the Panel. The HMTA, originally configured to support the ISS and Shuttle programs, is now engaged with every program, working diligently to provide full support. The Panel notes the imperative that health experts become involved early and remain engaged throughout the life of every human space flight program. Delayed or insufficient involvement of medical staff in spacecraft and project design can result in increased programmatic costs, schedule delays, and potentially greater risks to safety.

Acute and chronic effects of space radiation, Space Flight Associated Neuro-Ocular Syndrome (SANS), behavioral health considerations, food and pharmaceutical stability, autonomous medical capabilities, and integrated food/microbe-host/immune system considerations remain items of high interest and priority to the Agency. SANS, and other implications of cephalad fluid redistribution, deserve special mention as risks that continue to evolve (Figure 2). Venous thrombosis in the head and neck may be an emerging space flight-related health concern. Plans are in work to monitor long-duration crewmembers for these conditions.



C. International Space Station Extravehicular Activity Capability



FIGURE 3. Andrew Morgan performing the first of 10 spacewalks required to replace the P6 batteries

Extravehicular activity (EVA) remains one of the most hazardous activities conducted on the ISS. The program faces a challenging EVA schedule, with eventual P6 battery removal and replacement (delayed by a battery controller failure) and Alpha Magnetic Spectrometer repair (**Figure 3**). Currently, four EMUs on orbit are GO for EVA. Legacy EMU suit-life extension and upgrades remain in work, with planned capability extension to 2028.

Development of the next-generation prototype “Demo suit” is underway, organized under the Gateway Program, with deliverables consisting of one development, one qualification, and one flight unit, and ISS flight demonstrations planned for 2023. The xEMU is an organic NASA design-and-build project that will ultimately be transitioned to industry for production. No contract has been awarded yet for final production of this suit. In addition to replacing the legacy EMU, a derivative of the xEMU will likely be the suit used on the Artemis missions to the Moon.

The Panel is concerned about the ability of the ISS Program to maintain the legacy EMUs

and considers the development of replacement suits as a critical human space flight priority. While the Panel lauds the in-house xEMU project, it recognizes that the suit project has not enjoyed the status appropriate to its importance to all human space flight programs. The Panel urges NASA to apply rigorous program/project management discipline and adequate resources to this effort to enhance the chances of success. The Panel considers the development of the next-generation EMU as a human space flight imperative, which should be pursued independently of any changes in NASA’s overall space exploration strategy. ASAP recommendation 2019-02-01 addresses this concern:

Required Transition to Next Generation Extravehicular Mobility Units (EMU): NASA should begin an immediate transition to a next-generation Extra Vehicular Activity (EVA) suit system [Extravehicular Mobility Units (EMUs)], before the risk to EVA becomes unmanageable.



D. Assured Access to Low-Earth Orbit

While the CCP continues making progress, the Panel remains particularly concerned about assured ISS access. In anticipation of commercial crew vehicles, after the Soyuz return in October 2020, there are currently no more U.S. seats confirmed on Soyuz. The ISS is at risk of any CCP delay to launch crewed operations, which would reduce the total crew size to only three and would not include any U.S. astronauts in the current manifest.

The Panel is encouraged to have heard recently that NASA is developing contingency plans for continuity of U.S. Orbital Segment (USOS) operations. Lack of personnel with the requisite skill sets and training to operate the USOS would place the entire station at risk. The Panel encourages NASA to consider adjusting ongoing Soyuz and commercial crew seat assignments to reduce the risk to the Russian Orbital Segment (ROS) or USOS from any launch delays of the available launch vehicles. ASAP Recommendation 2018-04-02 captures this concern:

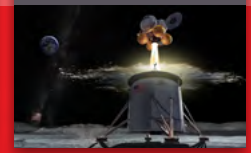
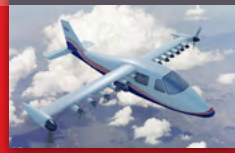
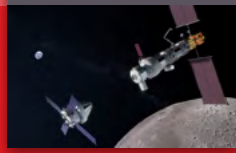
Action to Ensure U.S. Access to the International Space Station Given Commercial Crew Program Schedule Risk: Due to the potential for delays in the schedule for the first Commercial Crew Program (CCP) flights with crew, senior NASA leadership should work with the Administration and the Congress to guarantee continuing access to ISS for U.S. crew members until such time that U.S. capability to deliver crew to ISS is established.

As the ISS Program progresses, the Panel acknowledges there will be increased emphasis on commercial use. There also may be plans for further ISS life extension. The Panel recalls the previous detailed study of ISS components to extend expected life to 2028, and it encourages another such study if further programmatic extension is entertained. The lifetime of the ISS is limited, regardless of due diligence applied to lifetime extension efforts. There is value in transition planning to other platforms in LEO, anticipating end of life for the ISS. The Panel continues to recognize the value of permanent human presence in LEO, regardless of the platform.

E. Mishap Investigation Status

The ISS Program experienced two high-profile mishaps in 2018: an ISS cabin pressure leak due to a hole that appeared in the orbital module of a docked Soyuz spacecraft, and an anomaly that resulted in ascent abort of the launch of the Soyuz MS-10 spacecraft.

The hole in the Soyuz orbital module was determined to have been the result of a drilling operation. The etiology of this anomalous drilling operation has not been determined, but once the leak was detected, the crew and ground support personnel responded to effect repairs immediately.



The launch abort cause was determined to be a contact sensor separation pin that was bent during installation, causing incorrect separation of one of the Soyuz rocket's strap-on boosters. With the cause determined and corrected, Soyuz launch operations resumed within two months.

The Panel commends the ISS Program and our Russian partners for rapid investigation and resolution of both these mishaps, with extraordinarily quick return to normal operations. We recognize the merit of thorough mishap investigations, and strongly encourage that they be conducted openly and transparently and shared across the partnership, for the purpose of future mishap prevention.

F. International Space Station Deorbit Planning

Reference ASAP recommendation 2012-01-02:

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

The panel is pleased to note that work on the ISS Deorbit Strategy and Contingency Action Plan is proceeding, with a great deal of progress accomplished over the past year. NASA, the European Space Agency (ESA), the Japan Aerospace Exploration Agency (JAXA), the Canadian Space Agency (CSA), and the Italian Space Agency (ASI) have all concurred with the document and signed it. Negotiations continue with Russian counterparts, focusing on technical aspects of the deorbit operation.

III. Lunar and Deep Space Exploration

On December 11, 2017, the White House issued Space Policy Directive-1, entitled "Reinvigorating America's Human Space Program," which directed the Administrator of NASA to: "Lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities." It went on to say, "Beginning with missions beyond low-Earth orbit, the United States will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations," thus focusing NASA on the Moon as the next goal for human space flight. NASA had for many years been pursuing the tools necessary for exploration beyond LEO, namely, the Space Launch System (SLS) heavy launch vehicle and the Orion exploration capsule. Consequently, while the directive reaffirmed the commitment of the U.S. to return to the Moon, it did not materially change the course or alignment of NASA's portfolio of programs; the organization



was already on a trajectory, albeit with an uncertain schedule, to assemble the necessary components to send humans beyond LEO.

At the fifth meeting of the National Space Council in March of 2019 at the U.S. Space & Rocket Center outside MSFC in Huntsville, Alabama, the Vice President announced that the President was directing NASA to land a crew on the south pole of the Moon by the year 2024, thus imposing a specific schedule. At the time of the announcement, NASA had been maturing plans and moving forward on the Gateway Program, targeted at creating a platform in orbit around the Moon to facilitate long-term lunar exploration. With specific instructions to land humans on the Moon by 2024, NASA expanded their lunar architecture and identified requirements for a human-rated lunar lander and surface-rated extravehicular space suits as necessary to achieve the President's directive.

An ambitious deadline brings focus to an organization, and it is impressive how quickly NASA has coalesced toward a plan. NASA has had to think outside of the box and has adopted some agile and innovative approaches. To meet the 2024 deadline, NASA has had to move quickly, identifying the necessary architecture, understanding the requirements for each component, defining an acquisition strategy, working with the Administration and the Congress to acquire the appropriate budget, and engaging immediately with industry and their international partners. The resulting Artemis Program is both comprehensive and complex in scope (Figures 4 and 5). The program consists of numerous components, likely provided by a myriad of companies, with an acquisition strategy similar to that utilized for the CCP. In addition to the SLS and Orion, the program elements include a power and propulsion element (PPE); a habitat and logistics module (HALO); an additional logistics module; a human lunar landing system consisting (in the government reference architecture) of a descent stage, ascent stage, and transfer stage; and finally, a space suit designed for the lunar environment.

Independent of the acquisition strategy utilized, integration across the Artemis ecosystem will be challenging. NASA, as the lead organization for the Artemis Program, has the responsibility for mission definition and performance requirements and must act in a proactive manner to establish early in the program a process and organizational structure that will allow them to both mitigate risk and understand and define where risk should be accepted in both the design and operational phases. The additional complexity of integrating multiple complex elements, each procured as a "service" from different vendors, should not be underestimated—especially for the human lander system. Risk tracking and mitigation across such a complex ecosystem will require vigilance, constant communication, and forethought about how to navigate the contractual environment. During the nine-month study period, where NASA and potential contractors will work through details of systems' requirements and certification processes, integration approaches and procedural mechanisms should be addressed. The Panel believes the nine-month lunar lander study period will be an important exercise in influencing the risk posture of the program, and NASA should continue to articulate sound safety principles during these discussions. Specifically, the Panel will be interested in how NASA will track, define, and control the integrated risk across all of the components as the various designs evolve. The Panel has observed in the past that NASA has a well-documented and universally employed process for tracking and labeling risk, but given the increased

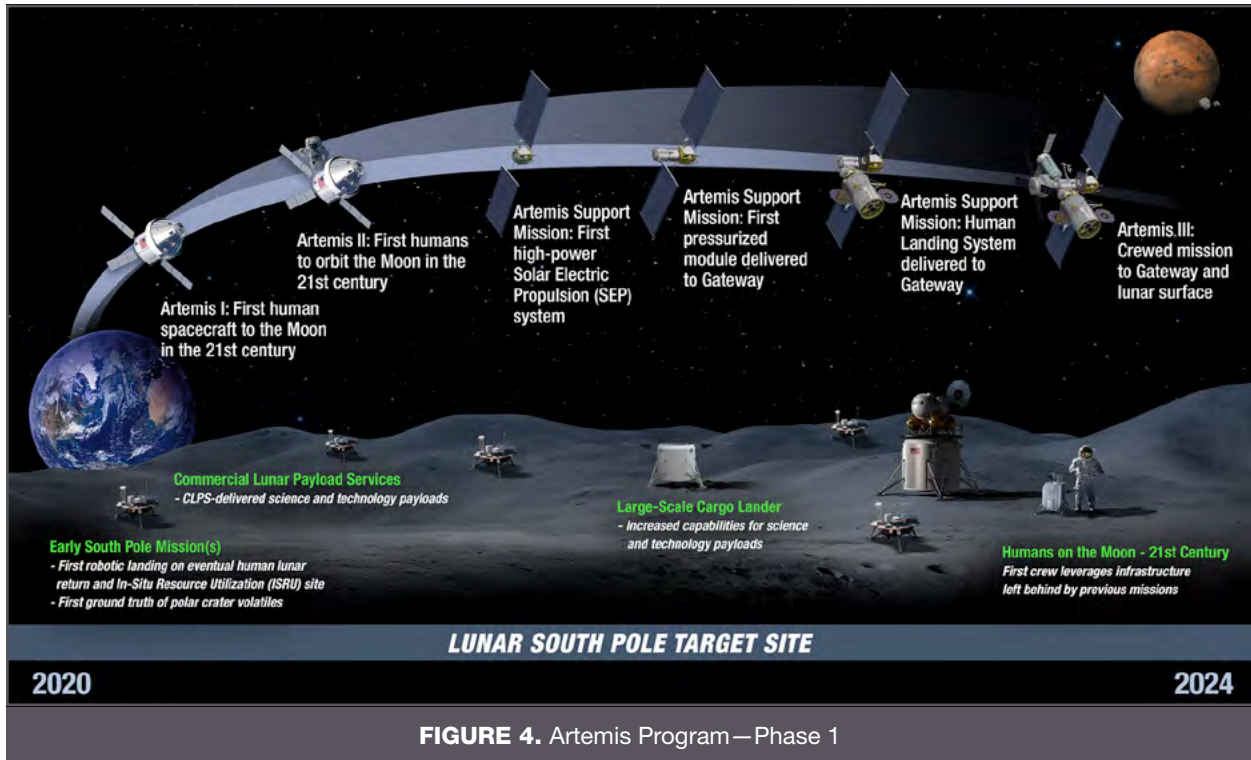


FIGURE 4. Artemis Program—Phase 1

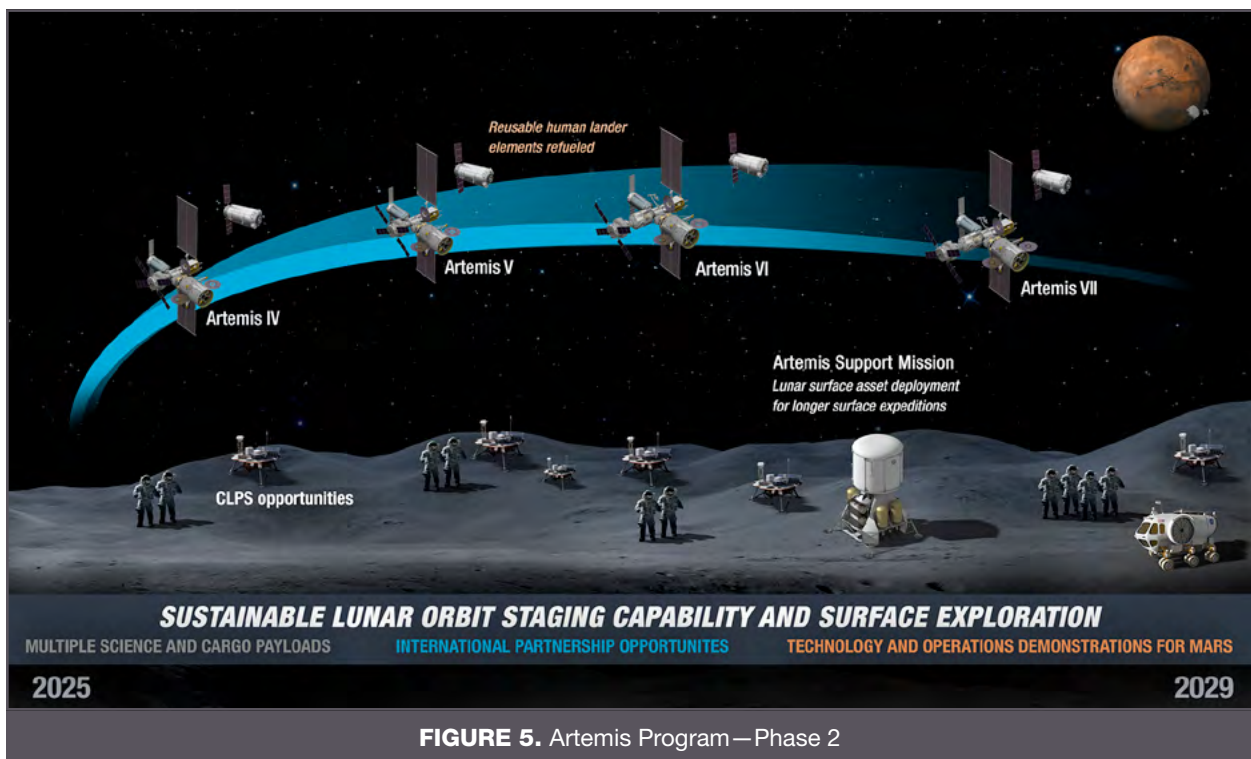


FIGURE 5. Artemis Program—Phase 2



complexity of the Artemis Program, the Panel will also expect a clear articulation of how the identified risks are being remedied, mitigated, or removed in an active fashion; merely tracking and carrying risk without a method of resolution as the program evolves will be unsatisfactory.

Part of the integral system required for the successful execution of the Artemis Program is the extravehicular surface suits that the crew will need. While NASA has managed to provide some funding for internal research and development on xEMUs (space suits), up to this point there has been no priority placed on producing a next-generation space suit. Space suits, which are essentially one-person spaceships, are complex and have stringent safety requirements. As previously mentioned, NASA has been conducting a prototype suit project over the past decade based the results of internal research and development efforts. This is evolving into a prototype development program for demonstration on the ISS. **Figures 6, 7, and 8** illustrate the current cadre of component providers for the xEMU development units. A final supplier list for the qualification and flight units has not been determined. There are many overlapping technical requirements and operational capabilities required for an ISS EVA system and a lunar surface suit. The exact same suit will not be sufficient for both applications because of the different environments in which the suits must operate (microgravity, where the crew translates via upper body mobility, vs. 1/6 gravity on a surface where lower body mobility is important). It remains unclear to the Panel how NASA is balancing the needs for a lunar suit with the increasing urgency of replacing the space suits on the ISS as they establish the prototype project for the xEMU. A structured space suit program, articulating such details, including a budget, schedule with critical milestones, and both the authority and responsibility to produce this critical capability, is recommended. Anything less than full, robust program-level attention to this system reduces the potential to not only field the capability but do so in a safe manner.

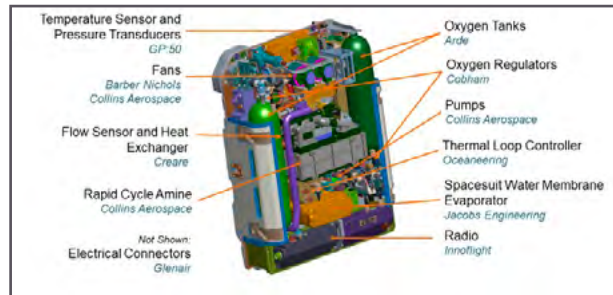


FIGURE 6. Portable Life Support System vendors (as of December 2019)

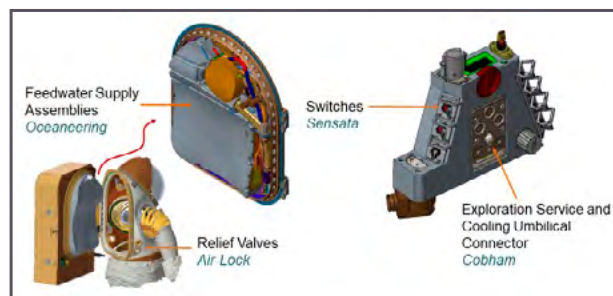


FIGURE 7. Portable Life Support System components inside the hatch/mounted to upper torso

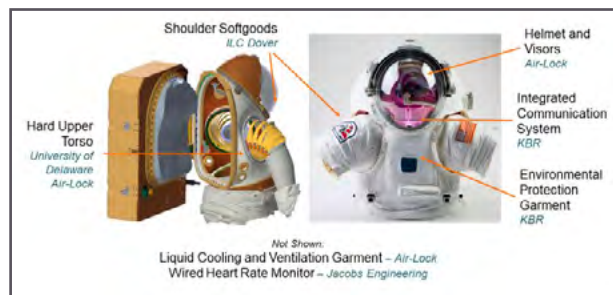
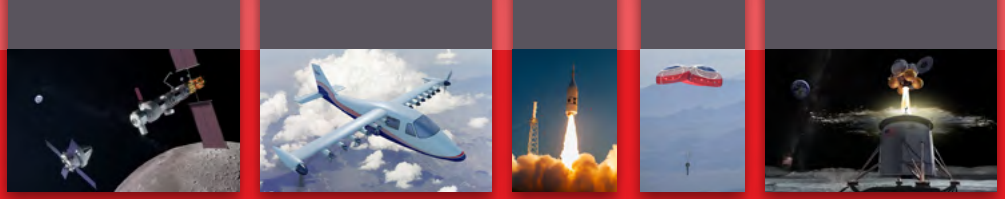


FIGURE 8. Pressure Garment System vendors (as of December 2019)



The directive to return humans to the Moon by 2024 is challenging and inspiring. As the Artemis Program begins, there must be a clear acknowledgment of the relationship between schedule, budget, and performance and how these three important program components are managed to directly impact the overall risk posture of the mission. NASA must be constantly vigilant in this area, implement strong program management principles, and make the appropriate adjustments to manage risk. Furthermore, as the goal of the Artemis Program is not only to return humans to the Moon by 2024, but to do so in a sustainable manner that supports continuing exploration endeavors, design, testing, and operational decisions must reflect this to manage risk for the long term.

Unlike the CCP, where NASA maintains a strong foundational experience base related to launching humans and operating in LEO, there is no current institutional knowledge, either at NASA or in the contractor community, for human operations in cislunar space. The number of “unknown-unknowns” facing the Artemis Program as it enters into design and operational development is greater than what the community has been accustomed to. Consequently, NASA should heed the lessons learned from the CCP, outlined in this report, as they construct the Artemis organizational structure. The experience base for early and frequent engagement with the contractors will be critical for NASA to gain insight into design maturity.

Preparing and communicating with the workforce will be especially important. Returning humans to the Moon by 2024, conducting sustainable lunar operations, and engaging in exploration leading to Mars are exciting goals for NASA’s workforce *and the most difficult challenges it has faced in decades*. Therefore, there remains as high a premium as ever on methodically identifying and managing risks. NASA leadership must deliberately focus on transparency and engagement throughout the management team and with the workforce. As the Panel has pointed out in previous reports, serial changes in direction and strategy can have a destabilizing effect on the workforce, leading to less transparency and consequently to a culture of risk-taking rather than one focused on deliberate risk management.

An unintended effect from this decade of change and uncertainty is that it can impact the workforce and management team’s decision-making and risk management approach. More directly, the dynamic environment imposed on an agency that is still involved in complex and hazardous operations in orbit (ISS) while simultaneously developing or sponsoring the development of new rockets, spacecraft, and critical equipment (e.g., the next-generation EMU, lunar rover, etc.) could lead the community to either accept some risks without adequate rationale or overlook other risks entirely.

Returning humans to the Moon is a natural evolutionary progression for the human space flight enterprise. As our species takes this next step to expand outward from our planet, it must be recognized publicly that the level of risk we are facing is greater than at any time over the last 50 years. As NASA embarks on this journey, it is important that all of its stakeholders—the public, executive branch and legislative branch leadership, the contractor community, and the NASA workforce—all acknowledge that this risk is present and commit to communicating openly about how it is being tracked and managed.



IV. Exploration Systems Development

Throughout the year, the ASAP reviewed the status of the ESD Program, to include the Orion Crew Module (CM) with the European Service Module (ESM), the SLS, and the Exploration Ground Systems (EGS). Each program of the overall ESD Program is making progress, but challenges remain, including the overall program integration under the recently announced Artemis missions. With the announcement of a Lunar 2024 vision put forward by this Administration in early 2019, EM-1 and EM-2 missions have now been renamed as Artemis-1 and Artemis-2, respectively. These two critical ESD missions have been milestones in the effort to return humans to the Moon, but with the establishment of the Artemis architecture, these missions must now integrate into a considerably more complex ecosystem. The Lunar 2024 enterprise includes requirements for public-private-international partnerships, a sequencing of multiple commercial launches, and an ambitious schedule mandate.

The Artemis-1 mission, which will demonstrate the critical test objective of taking an uncrewed Orion around the Moon and back, has well-defined priorities that are aligned with required risk reductions prior to the crewed flight of Artemis-2. For example:

1. Artemis-1 will demonstrate that the Orion heat shield performs as designed in the actual flight environment, especially the high-speed translunar re-entry, and will validate designed launch and ascent performance. Successful accomplishment of both these objectives is mandatory prior to crewed flight.
2. Artemis-1 will test vehicle and operational systems, including Orion deep space environment survivability, communications, propulsion and navigation systems, ground systems, mission control and management flight operations, recovery operations, and management of the deep space networks and facility support systems. In other words, Artemis-1 will carry out a robust end-to-end flight test of the integrated ESD system (except for the life-support systems) prior to crewed flight.
3. Recovery operations for the Orion spacecraft will also be verified and exercised, including the recovery of all special instrumentation, video, and avionics.

Beyond these three priorities, there are a host of other objectives that further reduce risk and validate overall performance of the entire ESD design and the system's ability to perform an Artemis mission. Upon the successful completion of the Artemis-1 flight test, NASA will launch the Artemis-2 mission, a mission designed to insert the crew into a temporary Earth-centric orbit for necessary functional checkouts, followed by a transfer trajectory to fly around the Moon with a free return. The mission design of Artemis-2 is maturing, and the Panel had the opportunity to review flight-abort mode design, crew pad egress capabilities, crew return and recovery operations, and detailed nominal mission profile analysis. Forward work for Artemis-2 includes crew recovery trainer development, crew abort training, further flight rule and procedure development and validation, integrated team



training, and off-nominal mission design. Mission design for crewed flights beyond Artemis-2 is to be determined at this time, as NASA is working through several studies to identify the overall lunar enterprise architecture.

A. 2019 Accomplishments and 2020 Milestones

The ASAP has been impressed with the amount of work accomplished this year in preparation for both Artemis-1 and Artemis-2. Every program of the ESD system exhibited significant progress. In addition to power-on testing, flight software testing, and structural qualification, two major Orion development milestones were achieved this year in preparation for Artemis-1 and Artemis-2. First, in a notable accomplishment of U.S.-European hardware integration, the CM and ESM were successfully mated and moved to the Plum Brook test facility for space environmental testing. Second, the Ascent Abort-2 test was completed at Cape Canaveral Air Force Station, successfully accomplishing a total of 38 flight test objectives. Final assessment following detailed review is expected by the time this report is published. In preparation for Artemis-2 and beyond, NASA has also announced an award of an Orion Production and Operations contract in September, thus providing an avenue for the acquisition of future Orion capsules.

An area of interest to the ASAP, full-scale structural testing enhances validation of the hardware design, enables higher-order flight modeling and simulation, and reduces uncertainty in the SLS integrated design, thereby enhancing safety and mission assurance (Figure 9). Notable SLS components that have been structurally tested include the Liquid Oxygen (LO_x) tank and the Liquid Hydrogen (H₂) tank, both of which required enormous test infrastructure and complex techniques. In addition, the engine section of the SLS—the most complex of the SLS components—was successfully mated to the core stage at Michoud Assembly Facility in preparation for the all-important “Green Run” at the Stennis Space Center (Figure 10). Artemis-2 SLS components are in development, and these complex fabrications are showing the positive effects of the classic learning curve; the program is experiencing a 40% decrease in production time and an 80% decrease in non-conformances for Artemis-2 component development, as compared to Artemis-1.



FIGURE 9. Structural test article for NASA's SLS

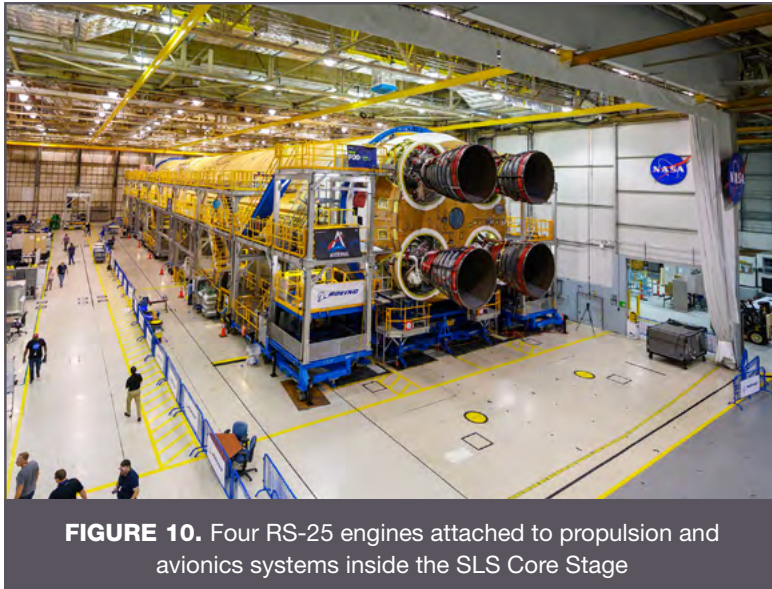


FIGURE 10. Four RS-25 engines attached to propulsion and avionics systems inside the SLS Core Stage

Another significant effort aimed at assuring the highest likelihood of flight test success is the “Pathfinder,” a full-scale simulated flight article that duplicates the weight, weight distribution, and dimensions of the SLS Core Stage. A critical test and training article designed to reduce the risks of handling the SLS Core Stage, the Pathfinder facilitates a “dress rehearsal” for the 2020 Green Run operation, including a crucial “break-over” operation that moves the core stage from horizontal to vertical (and after the test,

back to horizontal). The Pathfinder also supports critical fit checks of both the test stand and the core stage transportation vehicles, and personnel who must handle the flight hardware have had the advantage of using the Pathfinder to support their training for a “first of its kind” rocket. The Pathfinder is now at KSC to support KSC personnel in preparation for the Artemis-1 launch and beyond.

Software for the EGS has been progressing in a satisfactory manner. For example, initial avionics software verification in the Software Integration Test Facility (SITF) was completed late this year. The Mobile Launcher (ML) was successfully rolled to the Vehicle Assembly Building (VAB) in September and then successfully rolled out to the launch pad in November. Systems verification and validation steps are expected to be completed by the end of the year, and modification of the Space Shuttle launch pad Emergency Egress System to support the ESD design is in work.

The ASAP notes that an immense amount of work on the ESD Program has been successfully accomplished in 2019 and that the careful planning for important risk-reducing milestones, such as structural testing and the use of the Pathfinder, have played extremely important roles in helping NASA to better understand the nature of this brand-new rocket with its exploration mission design. Looking forward to 2020, one of the most important milestones of the entire ESD program is the Green Run of the SLS Core Stage, a test event that the ASAP considers as essential to risk reduction ahead of the first flight of the SLS (the Artemis-1 mission). This end-to-end test of the rocket, fired for a duration that matches inflight requirements, will validate critical integrated performance, reduce uncertainties, and improve mission assurance and safety. Critical Orion development activity in 2020, centric to the Artemis-2 crewed mission, includes the installation and testing of the ECLSS at KSC, and the delivery of Artemis-2 core avionics and software.

As directed by this Administration, the overall Artemis initiative has an announced goal of “boots on the Moon” by 2024, generating much excitement both within and beyond the NASA workforce and



partnerships. However, to achieve the mandate, NASA must launch the Artemis-3 mission by 2024, in concert with a host of enterprise architectural elements for Moon and Mars exploration. To state in simpler terms, NASA will be required to launch a brand-new rocket at least three times within the next five years. To NASA's credit, the team is investigating every opportunity to optimize this ambitious schedule without impacting safety and mission assurance. Nonetheless, within this context, the ASAP would like to provide the following observations about an ongoing area of concern for the ESD Program.

B. Ongoing Area of Concern: Integrated Risk Management

A clear, integrated risk management process for a “system of systems” as complex as ESD is crucial for managing the overall risk at a level necessary for human space flight. The three components of the ESD—the Orion/ESM Program, the SLS Program and the EGS Program—have each individually worked through important milestones and managed technical challenges during development. Of interest to the Panel, however, is how the integration of the three ESD elements is managed consistent with systems engineering and integration principles, especially given the complexity of the overall system and the austere operational environments the overall system will face.

The ESD Program has a cross-program Systems Integration Office that is intended to manage integrated concerns broader than the individual ESD Program elements. This office has not only cross-program technical issue resolution teams, but also integrated schedule/cost assessment activities. The ASAP observed that many of the risks captured as “integrated” were programmatically oriented (e.g., funding and schedule risk) as opposed to technical risks that require engineering rework, additional integrated testing, or operationally targeted solutions for risk mitigation. While it was gratifying to see the focus on synchronizing various development schedules across the ESD test programs, it was concerning to see the term “integrated risk” applied to program management processes. What was less clear to the Panel was whether integrated technical risks—especially those related to safety and mission assurance—are truly elevated above program management concerns. The Panel was left with the impression that program management appeared to be given “equal billing” within the integrated risk management framework. This will be a continuing area of concern for the Panel, particularly given the ESD mission growth to support the Artemis exploration enterprise.

During 2019, the Panel noted that development of the Orion Program has its origins in the now-cancelled Constellation Program and that some assumptions related to early risk adjudication may have evolved over time. As initial conditions and assumptions change during a program's evolution, it is extremely important to have discipline, clarity, and transparency in how important risks are positioned. In particular, tracking the risk-related assumptions, whether they change as development evolves, and when to reexamine the risk posture in light of those changes, is a critical aspect of due diligence in systems engineering. The ESD Program Manager has an initiative to review legacy risk acceptance documentation, and given the complexity of the ESD/Artemis Program, the ASAP will continue to monitor NASA'S progress.



The ASAP has expressed concern that the workload related to concurrent development, design, and mission planning for the Artemis-1, -2, and -3 dilutes the ESD resources; essentially, the same community of engineering personnel are being spread across development, processing, and operations simultaneously as various parts of the ESD Program progress. As mentioned previously in this report, NASA has more critical, ambitious programs advancing in parallel than at any other time in the Agency's history. In light of the ESD Program being recast as the lynchpin of the Artemis/Lunar 2024 mission, this will be a continuing area of heightened interest for the ASAP in future meetings.

V. Commercial Crew Program

A. Progress in 2019

Following the retirement of the Space Shuttle in 2011, one of NASA's highest priorities has been to regain the capability to launch American astronauts into space, on American rockets, from American soil. In 2019, the CCP made considerable progress toward this goal. Both Boeing and SpaceX had targeted their initial crewed flights before the end of 2019, and although those milestones will now likely occur in 2020, it is clear that both providers are getting close to launch. The companies, in close cooperation with NASA, are now focusing on addressing the remaining technical issues that must be resolved before crewed flight.

SpaceX executed a successful Demo-1 mission in March 2019 (Figure 11), yielding a combination of developmental verification and validation data. During the Demo-1 flight, the SpaceX team



FIGURE 11. The SpaceX Dragon capsule approaches the ISS during the Demo-1 mission



successfully demonstrated its ability to integrate and execute with the ISS team, as well as to conduct operations involving the end-to-end process of launch, docking, deorbit, splashdown, and recovery, as this process relates to crewed mission parameters. The Demo-1 flight test provided a wealth of data that allowed SpaceX to continue design maturation. In preparation for Demo-1, during discussions about the path to certification, NASA and SpaceX identified several configuration changes and subsequent qualification work that needed completion before the launch of Demo-2. Significant milestones required prior to Demo-2 include the In-Flight Abort Test and approximately 10 parachute tests using the new Mark 3 main parachute system, a recent design upgrade from the Mark 2 system that is intended to increase load margins.

Following the AMOS-6 mission launch pad anomaly in September 2016, there has been a tremendous amount of work done, both by NASA and by SpaceX, to better understand the design and operational parameters associated with composite overwrapped pressure vessels (COPVs). A multi-year study of COPVs has resulted in advancing the state of the art and increasing understanding of grain size, ignition risks, and non-destructive testing techniques. There has also been considerable progress made in evaluating both the benefits and the risks associated with crew insertion prior to propellant loading, sometimes referred to as “load-and-go.” During the past year, both issues and subsequent corrective actions have been thoroughly reviewed by NASA engineering and safety officials, and the residual risks have been accepted by the Program Manager. After many months of discussing these topics with both NASA and SpaceX, the ASAP is satisfied that NASA has executed an appropriate risk management process to address these issues.

In April 2019, SpaceX experienced an anomaly during an attempted static fire testing of the SuperDraco propulsion system on the Dragon capsule, resulting in the loss of the vehicle. A formal investigation, which included NASA participation, identified a number of corrective actions and design changes, and once implemented, a subsequent static fire test was successfully completed to prepare for the In-Flight Abort Test.



FIGURE 12. The Boeing Starliner descends under parachutes at the conclusion of the pad abort test

Boeing completed a pad abort test at the White Sands Missile Range in November 2019. The purpose was to validate the end-to-end performance and functionality of the Launch Abort System. The four abort engines fired for about 5 seconds, with the spacecraft reaching a maximum altitude of approximately 4,400 feet above ground level. Thrusters reoriented the vehicle to the proper attitude, followed by a series of pilot, drogue, and main parachute deployments. Although the trajectory matched the pre-test predictions, only two of the three main parachutes deployed properly, as shown in **Figure 12**.



The root cause of the non-deployment was later identified as the lack of a secure connection between the pilot chute and the main chute lanyard. Additional tests and inspections have been added to the procedures to prevent a reoccurrence of the problem.

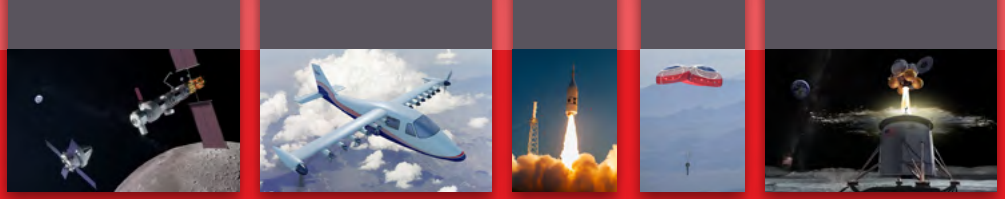
In December 2019, as part of Boeing's Orbital Flight Test (OFT) mission, the CST-100 Starliner was launched into space on a United Launch Alliance Atlas V rocket. However, due to an anomaly with the Mission Elapsed Timer, the spacecraft burned more fuel than anticipated prior to the orbital insertion burn, and rendezvous with the ISS was not possible. The impact of the anomaly on the launch date for the Crew Flight Test (CFT), if any, will depend upon the results of post-flight analysis.

Both SpaceX and Boeing have work remaining on parachutes. Results from recent tests indicate that the math models traditionally used by the parachute community, even as far back as the Apollo program, may not have accurately predicted the margins present in the design, especially for asymmetric loading cases. Consequently, additional parachute tests have been identified by both providers, both to validate the updated models and to demonstrate that the as-designed systems have the appropriate margins for crewed missions.

B. Observations and Recommendations

Over the past year, the ASAP has been paying close attention to the test philosophy of both providers and the relationship between the test configuration and the final design for the crewed missions. Significant changes in design between test flights and crewed flights potentially undermine the capability of the uncrewed flights to mitigate the risks. One approach to this issue would be to require that no configuration changes be made between uncrewed and crewed flights. In such circumstances, the uncrewed missions could serve as "dress rehearsals" for the first flights with crew. Another approach would allow configuration changes in cases where design changes address known problems or would otherwise increase the vehicle's safety and reliability. In some cases, this approach could also allow the preliminary test flight to be accomplished earlier in the design maturity, thus providing data to inform the design. Both philosophies have advantages, but regardless of which approach is taken, the ASAP believes that the final plan should institute a robust, disciplined risk management process that defines the hardware margins and operational envelopes; does careful vehicle configuration control; and understands the safety margins and, when appropriate, the limitations of analysis and the value of flight tests. For example, highly complex systems such as heat shields and asymmetrically loaded parachutes should be demonstrated within their operational envelopes prior to certification for crewed missions, and those kinds of tests have been appropriately included in current planning.

In 2019, the Panel reviewed several issues with flight hardware that are presently in work toward resolution. In one particular instance, an issue with flight hardware subcomponents was discovered during some integrated vehicle testing. While this was yet another validation of the value of integrated testing, it was determined that these particular subcomponents were not built to spec but, in spite of



that, had apparently passed the subcomponent qualification testing. The subcomponents themselves are very common pieces of hardware for spacecraft, and there is a long history both at NASA and in industry with qualification-testing this kind of hardware prior to acceptance and integration. In this case, the actual quality of the subcomponent hardware was compromised in manufacturing, but the commonly used qualification testing of the subcomponent, developed by experience over time, did not catch the problems with the hardware. Although integrated testing caught this particular issue, it is a good reminder that supply chain challenges are manifesting across the aerospace industry and that a robust, proactively aggressive qualification testing and surveillance program is one of our best defenses in the face of these challenges.

The CCP has been carried out using a very different approach from previous human space flight programs that were managed by NASA. In general, the partner companies were responsible for developing the spacecraft design, completing the necessary testing to demonstrate performance, safety, and reliability, and then ultimately operating the systems to transport NASA astronauts to LEO as a service. Although NASA attempted to reduce the number of prescriptive requirements that the companies had to meet, NASA retained the final approval authority on the systems through a thorough certification process, which involved submittal of test data, analysis, or other evidence that NASA's overall standards for safety and mission assurance were being satisfied.

As the ASAP has pointed out previously, SpaceX and Boeing have very different philosophies in terms of how they develop hardware. SpaceX focuses on rapidly iterating through a build-test-learn approach that drives modifications toward design maturity. Boeing utilizes a well-established systems engineering methodology targeted at an initial investment in engineering studies and analysis to mature the system design prior to building and testing the hardware. Each approach has advantages and disadvantages. However, regardless of the development path chosen, each company must fulfill the certification requirements established by NASA. A challenge that NASA has faced, especially in light of the fact that both providers are submitting the required certification materials in the same timeframe, has been to manage the work across the relatively small government teams to ensure that the data provided is sufficient to evaluate whether the systems are safe and reliable and meet the government's requirements. Although CCP office workload and other potential contributors to schedule pressure continue to be a concern for the ASAP, we are pleased to report that we have not seen any evidence that NASA is yielding to schedule pressure by skipping important development milestones, removing test and analysis content, or backing away from well-established margins of safety.

Continued development delays in the CCP program flights for reasons of safety and mission assurance have put NASA at risk for a disruption in the U.S. presence on the ISS. Attempting to mitigate this issue may lead to a push for greater risk acceptance by NASA via a compressed program schedule. To counter the safety risks of such schedule pressure, NASA (along with Congress and the Administration) should consider contingency plans, including all available transportation options, for continuity of operations. The Panel highlighted this issue in Recommendation 2018-04-02 in last year's annual report:



Action to Ensure U.S. Access to the ISS Given Commercial Crew Program Schedule Risk:

Due to the potential for delays in the schedule for the first CCP flights with crew, senior NASA leadership should work with the Administration and the Congress to guarantee continuing access to ISS for U.S. crew members until such time that U.S. capability to deliver crew to ISS is established.

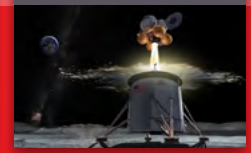
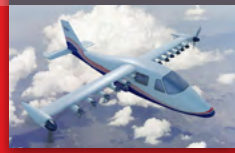
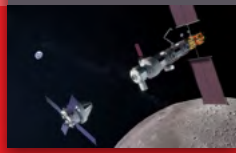
As NASA approaches the resumption of launching humans on U.S. spacecraft, it is very important that the language in the NASA Authorization Act of 2005 requiring a Presidential Commission for mishap investigations be reviewed and revised. The best time for that to be accomplished is before a mishap occurs. The Panel identified this concern in 2015 as part of Recommendation 2015-05-02; however, the issue has not yet been resolved:

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

Once the demonstration flights for SpaceX and Boeing have been successfully completed, the follow-on missions to the ISS, known as Post Certification Missions, will be conducted under Federal Aviation Administration (FAA) launch and reentry licenses. The division of responsibilities will be similar to what is being done currently for Commercial Cargo missions. It will be important for NASA and the FAA to work together closely to ensure that the process can be accomplished efficiently and effectively, and without unnecessarily burdening the providers with duplicative paperwork. We have not yet seen from NASA the "streamlined" processes they intend to use to assure a commercial approach while still preserving safety and mission assurance, but subsequent to the crewed demonstration missions, that will be an area of interest for the ASAP.

C. Commercial Crew Program Lessons Learned

Even though the development phase of the CCP has not yet been completed, many of the most challenging technical development issues have already been resolved. Because the CCP will play a key part in NASA's future human space flight endeavors, and because the program was conducted so differently from previous NASA programs, the ASAP believes that this is an appropriate time to consider the lessons that have been learned along the way, so that they can be applied to future programs. For example, many of the key elements of the Artemis Program are planning to use the same acquisition



methodology as the CCP. With a more compressed timeframe and both larger scope and greater risk, the hard-won lessons of the CCP program will be important to pass along. Some of the most important lessons are described below.

- **The importance of adequate and consistent funding.** It can be extremely important for NASA to have adequate funding at the beginning of a major program. The CCP was underfunded in the early years, which strongly impacted the pace and technical evolution of the designs. And as the Panel has noted many times in the past, Continuing Resolutions are very disruptive to program management and the overall budget process.
- **Clear and well-articulated performance-based requirements.** The government traditionally likes to specify a large number of very detailed, very prescriptive requirements. If instead NASA can articulate what it wants the system in question to do rather than exactly how to do it and can include a clear identification of the required risk posture, the resulting system can often take advantage of innovation and advanced technologies in a very beneficial way.
- **A well-thought-out acquisition strategy.** The CCP has clearly demonstrated that the use of Space Act Agreements (or Broad Agency Announcements, Other Transaction Authority agreements, or equivalent arrangements), along with firm fixed-price contracts and performance-based milestone payments, can result in significantly lower development costs. At the same time, that approach puts much more responsibility on the government to make sure that requirements are correct at the start of the program and to guarantee that there is an ability for the government to step in and respond appropriately to unexpected developments or technical surprises during the program. It is also important for NASA to take a robust and active approach to directing and managing integration across all program elements in order to control risk and ensure an appropriate safety posture for the mission.
- **The benefits of competition.** The value of working with multiple providers has been demonstrated on numerous occasions with both Commercial Cargo and Commercial Crew, with each company being challenged by its competitors to do better on cost, performance, and safety. In addition, the availability of multiple providers has proven to be very helpful after one provider experiences an accident or unexpected test results.
- **Early engagement with industry.** NASA learned on both the Commercial Cargo and Commercial Crew programs the importance of establishing an integrated NASA-industry team at the beginning of the program to build a sense of mutual trust. Having government representatives embedded with key providers early, and communicating regularly and frequently, can really pay off, as opposed to merely exchanging paperwork between parties and/or having quarterly teleconferences. The Panel would love to see that same kind of relationship between NASA and industry right from the start on Artemis and other future programs.
- **Defining and executing to a realistic schedule.** Having a set of clearly articulated and communicated objectives, ambitious but attainable schedule goals, and a sense of urgency in the workforce can be a very good thing. At the same time, the Panel recognizes the importance of



avoiding “launch fever” and the kind of overwhelming schedule pressure that can lead to short-cuts or inappropriate programmatic decisions that can compromise safety.

VI. Aeronautics and Air Operations

A. NASA Aircraft Management Information System

NASA Aircraft Management Information System (NAMIS) funding under the budget line of the Chief Information Officer (CIO) appears secure for the immediate future, and user complaints about service or updates have been minimal. The current future-year funding plan profile for NAMIS adds a 3% escalation each year, which is considered adequate for continued operation at current levels. NAMIS did receive the first portion of fiscal year 2020 funds prorated as expected in accordance with the current government Continuing Resolution.

The Panel continues to support the universal use of electronic publications for all aircraft and inclusion of support equipment and external payloads within NAMIS. The use of NAMIS to track spare parts was agreed to by the logistics directorate and appears to be satisfying their requirement, thus relieving the potential to install another separate tracking system.

Overall, the ASAP has heard positive feedback at the Centers on the functionality of NAMIS to support operations and maintenance. The Panel has also found that some Centers are already using NAMIS for ground support equipment maintenance and calibration requirement tracking, which we believe is a best practice that will hopefully be adopted by all Centers operating aircraft.

B. Contract Air Services

NASA aircraft are primarily funded to operate with resources from the mission directorates, which are the largest users of NASA aircraft in support of their science and logistical mission requirements. The funding provided by the mission directorates not only covers operational and maintenance costs, but also must include the life-cycle sustainment cost of all NASA-owned aircraft.

During 2019, NASA continued to capitalize on the efficiencies and savings that Contract Air Services (CAS) can provide for the end user, especially small-footprint, small-payload airborne science experiments. An example is illustrated in [Figure 13](#).

Aircraft operated under contract for NASA missions are operated under the provisions of the Public Aircraft Operations (PAO) section of Federal Aviation Regulations (FARs). When operated under PAO in support of a NASA mission, the Agency would be responsible for the oversight of specific maintenance and operations. NASA has an obligation to determine that airworthiness, maintenance, training, and operational safety requirements are met by the contractors. Providing effective and thorough oversight of CAS operators requires manpower and expertise. Hence, the use of CAS creates the

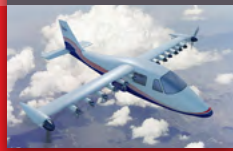


FIGURE 13. Contracted DC-3 flying in support of Operation Ice Bridge

same or similar demand on flight support personnel as does the operation of NASA aircraft. However, the aviation workforce assigned to the Centers is allocated based on the resident aircraft and not the total flight hours conducted. For Centers with highly active CAS operations but a low number of NASA aircraft operations, it is potentially possible to have insufficient personnel to support the total flight operation in a safe manner. Consequently,

staffing requirements to include CAS oversight may require future personnel level adjustments based on the total flying hour program regardless of the source of the aircraft.

C. Aeronautics Research

Armstrong Flight Research Center (AFRC) recently accepted the Electric X-57 Maxwell demonstrator aircraft (Figure 14). The aircraft is being introduced into flight operation in stages and its propulsion systems will progress to finally operating on electric power. Recently however, the aircraft failed its pre-acceptance inspection for wiring, and the ASAP is interested in learning what corrective action will be taken to prevent a reoccurrence.



FIGURE 14. X-57 Maxwell aircraft prepares for flight operations



The X-59 or Low Boom Flight Demonstrator (LBFD) aircraft is still in the build stage and has not yet commenced operations. While sonic boom work has been ongoing for several years using other aircraft, this X-plane effort is clearly the most significant project undertaken to date and contains risk for collateral damage to people or property under the flight path. The reason this project entails a somewhat unique operational risk is due to the requirement that it fly over populated areas to gather data on the human response to sonic boom. Under normal circumstances experimental aircraft, especially “X-aircraft,” are limited in any flight operations over populated areas to protect residents in case of aircraft emergencies. Because it will operate over populated areas, this additional risk will require considerable attention to safety and careful planning by the test team.

The Panel continues to emphasize the importance of any X-plane flying in a diligently controlled and methodical manner to ensure that risks are mitigated for the aircraft and crew flying them. In addition, as an X-aircraft is an exceedingly expensive “one-off” vehicle and its loss or damage can be devastating to the research program and rob the nation of critical technical data, a careful, well-thought-out approach to flight operations is warranted.

D. Comments on the Fleet and Aging Aircraft

Long-term strategy for all NASA-owned aircraft is determined by examining data such as use in supporting human space flight, sustainability of the airframe and associated systems, and crew training requirements. Additionally, most NASA aircraft perform their missions using the “Public Use Aircraft” designation. Under this process, the necessary mission modifications are the sole responsibility of NASA, who must validate their airworthiness from the perspective of safety.

Adding complexity to fleet operations is the fact that NASA operates some very unique aircraft. The most unique aircraft in the NASA fleet, the Boeing B-377SGT “Super Guppy Turbine” (Figure 15) fulfills the role of transporting oversized aerospace cargo. NASA obtained the aircraft in 1997 after its service to Airbus Industries. The Super Guppy is an aging airframe, and logistics and parts supportability are increasingly difficult. Since NASA does have long-term, large-volume, high-mass transport mission requirements, the long-term viability of the Super Guppy and its ability to meet future mission needs are a concern, and the ASAP encourages NASA to examine alternative platforms that might meet the requirements.

Another aging aircraft in the NASA fleet is the Northrop T-38N operated in support of Astronaut Space Flight Readiness Training. Sustainment for the T-38N must include support of the current avionics suite, yet the current circuit boards and glass on the avionics displays are obsolete and may not be currently manufactured. A strategy for the long-term support of this program is required.

Other aircraft, such as SOFIA and the DC-8, which support science missions, and the F-18 and F-15 aircraft, which support aeronautical research, illustrate the very specialized fleet necessary to support NASA’s varied missions. Long-term support of this capability requires a strategic plan to assure future sustainment. Although the NASA fleet aircraft are safe to operate today, they continue to get



FIGURE 15. “Super Guppy” aircraft

older and become more difficult to support. A situation where operational aircraft are so out of date and difficult to maintain that they become flight safety risks would be unacceptable. By establishing and gaining approval for a long-term strategic plan, NASA can have reasonable assurance that their fleet will both retain the capability for mission support and be able to function in a safe manner.

E. Unmanned Aircraft Systems (UAS) Operations

Last year, the Panel commented on the alignment of NASA directives concerning UAS operations with FAA/FAR 107.41 requirements and limitations for airworthiness. The Panel’s investigations have not encountered any evidence of difficulties with this issue. It appears that the risks associated with the NASA operations of UAS have been effectively mitigated. Current NASA policy appears to be sound for both operations and training, and, most importantly, the policy is being enforced.



VII. Safety Culture

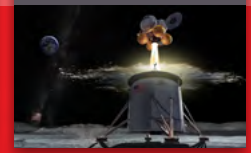
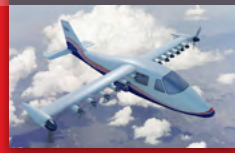
A strong safety culture within NASA is essential. Historically, NASA's safety culture has been through periods of change, which is normal for any organization. With NASA specifically, the occurrence of high-visibility accidents such as Apollo 1, Challenger, and Columbia resulted in organizational and policy changes intended to prevent any such accidents in the future. The challenge, of course, is to maintain a high level of vigilance and not allow complacency to set in, especially after years of accident-free operations. The foundational element of maintaining mishap-free operation is a strong safety culture functioning at a high level. A strong safety culture requires leadership to consistently demonstrate commitment to safety, and safety to exist as a core value that is woven into the processes throughout the day-to-day operations of the organization. The important role that leadership plays in supporting the safety culture lifecycle cannot be over-emphasized. Leadership decisions that appear to disregard established safety processes can quickly undermine even the most mature and high-functioning safety culture.

An important concept that must be understood at all levels of the organization is that safety must not be regarded or treated as merely a priority. Priorities can be reassigned, so if safety is considered as a "priority," it is subject to the risk of being displaced by something of higher priority, such as schedule. Instead, safety is a value that must be incorporated into every priority, across the enterprise. Existing NASA processes have safety "built into" their design, but they must be executed as designed to fully realize the design goal. For example, there are numerous quality assurance checks that must be completed when preparing a piece of space flight hardware. These quality checks are designed to trap material flaws, as well as to identify human errors and process escapes that could occur during assembly. Unrealistic schedules may result in even greater perceived schedule pressure at the technician level and can easily translate to rushing, corner-cutting, and ultimately missed opportunity to identify safety issues because the established process was not executed as designed.

The Panel has monitored the status of NASA's safety culture for several years, documenting thoughts and findings in reports, minutes of quarterly meetings, observations of safety culture indicators, and evolving formal recommendations. Concerns expressed by the Panel in previous years led to an insight visit to the NSC in July of 2019. A brief history of the Panel's concerns, observations made during 2019, and the insight visit to the NSC will be detailed below.

A. Recommendations and Efforts to Resolve Concerns over NASA's Safety Culture

The Panel began its inquiries into the health of NASA's safety culture a few years ago and visited the NSC to gain insight into the Safety Audit Process. In 2017, the Panel made the following Recommendation, 2017-02-01:



Schedule and Cycle of Safety Audits: NASA should establish, prioritize, resource, and implement a rigorous schedule of audits, executed by the Office of Safety and Mission Assurance (OSMA) and conducted at the Center level, to ensure that documented safety requirements, processes, and procedures are consistently applied across the Agency.

Early in 2018, the Panel learned of targeted surveys being conducted by the OSMA. Consequently, in May 2018, we proposed the following revision to the existing recommendation, with a revised title (Recommendation 2018-02-01):

NASA Safety Assurance Process Scope and Quality: NASA Safety and Mission Assurance should have a coordinated, in-depth system of safety assurance tools and processes to verify effective programmatic safety compliance, system safety practices, safety process function, safety culture, and overall safety posture at all levels of the organization.

In the 2018 Annual Report, we discussed the Panel’s goal to see NASA demonstrate a “generative” safety culture, one where safe behavior is fully integrated into all activities. At the time the 2018 Annual Report was prepared, there was a lack of clear evidence that NASA’s safety culture was operating at the generative stage in all areas, leading to concerns that the safety audit process did not ensure effective implementation of both workplace and system safety-related practices and processes.

NASA’s safety audits are intended to thoroughly evaluate its programs and to obtain appropriate metrics. The evidence gathered helps ascertain the effectiveness and maturity level of the safety culture. In addition, safety audits should also encourage practices such as peer review, best practice benchmarking, and physical audit of workplace activities to ensure safety. The safety audit process should begin at the program design stage and capture metrics such as the number of safety concerns raised; how many were resolved through the hazard control hierarchy; how many were elevated to senior management levels for acceptance of residual risk; how many dissenting opinions were raised; how many quality escapes resulted or could have resulted in near misses or incidents; and how many actual mishaps, incidents, and close calls occurred. Safety concerns can and should be raised and addressed throughout the lifecycle of a system or program. Milestone reviews, such as the one depicted in **Figure 16**, provide a high-level forum for identifying safety concerns and formally documenting the process for addressing and resolving them.



FIGURE 16. High-level NASA milestone review



At the Panel’s second-quarter meeting of 2019, the OSMA gave an in-depth presentation on the status of NASA’s assessment of its Safety and Mission Success (SMS) capability and its development of processes to not only maintain Agency-wide SMS situational awareness, but also respond to indicators of suboptimal SMS practice and culture. Based on the information we received, the Panel determined that NASA’s safety culture was solidly at the “calculative” stage. The “calculative stage” is one where systems and processes are in place to carry out required safety work, but one that falls short of the desired “generative” culture. In a fully “generative” culture, safety policies are embraced and implemented at all levels of the organization. NASA still has remaining work to achieve a “generative” safety culture, and to achieve that goal, the Panel encouraged all NASA leaders to take full ownership and accountability for SMS systems and processes and enforce their use.

As noted previously, the Panel’s ongoing concerns with the safety culture and the safety audit process prompted a return to the NSC for an insight visit in 2019. This insight visit is discussed in the next subsection.

B. ASAP Insight Visit to the NASA Safety Center, July 10–11, 2019



FIGURE 17. The NSC near Cleveland, OH

On July 10–11, 2019, three ASAP members visited the NSC near Cleveland, Ohio (Figure 17). The NSC supports safety and mission assurance (S&MA) in four major areas: mishap investigation, technical excellence, audits and assessments, and knowledge management. The NSC provides a wide breadth and depth of information, from policy to education, related to maintaining and promoting a healthy safety culture.

One of the programs available from the NSC is the STEP. The STEP is available as online learning, providing continuing education credits designed to teach safety professionals in particular, and all employees in general, about system safety. The program has multiple levels, with the Level 1 class specifically targeted to benefit the engineering workforce. Higher levels provide more advanced content for S&MA professionals.

Surprisingly, the Panel found that there existed no requirement across the Agency for employees to take the basic safety training course. Indeed, with the exception of KSC, where the STEP Level 1 class is required for all new hires, the workforce remains largely unaware of the program.



At the ASAP fourth-quarter meeting at JSC, the ASAP made the following recommendation (2019-040-1):

Required STEP Training for All NASA Personnel. Given the importance of creating a culture of safety across the NASA workforce, and the availability of a resource to promote that goal, the ASAP would like to recommend that NASA adopt an Agency-wide requirement for all employees to complete the STEP Level 1 training course.

C. Observations Made in 2019 Related to NASA's Safety Culture

In early 2019, when the government was reopened after an extended shutdown, safety stand-downs were conducted at all Centers as NASA and contractor employees returned to work. This action arguably helped prevent the occurrence of near misses or even mishaps, especially at high-energy facilities like wind tunnels, by allowing personnel to focus on safety first after an extended absence from the workplace. The Panel was impressed and regarded this as an indicator of an improving safety culture.

Another positive observation was related to the process for allowing dissenting opinions. Multiple dissenting opinions about a serial vs. parallel design for the ESM propulsion system led to a closer examination of the system, ultimately resulting in design improvements. Specifically, redundant seals and pressure transducers were added to valves and interconnecting piping to achieve better reliability out of the serial configuration. This process of allowing dissenting opinions and effectively seeking resolution of safety concerns was also seen as a safety culture success story.

At the second-quarter meeting of 2019, the Panel identified several important milestones that must be achieved before a crewed flight of the SLS and Orion spacecraft. One of the most critical such milestones is the Green Run test of the rocket's core stage at Stennis Space Center. The Agency decided to continue with the SLS Green Run, in spite of intense schedule pressure. The Administrator was a strong proponent of continuing with the Green Run. This was an example of leadership being key to a healthy safety culture and was regarded by the Panel as a positive observation with respect to safety culture.

D. Safety Culture Path Forward

Overall, the Panel's previous concerns over the NASA safety culture have been adequately addressed. As noted herein, observations and objective metrics indicate that NASA leadership has made great strides in demonstrating that it is committed to safety and that it expects nothing less from the workforce. An ASAP insight visit is being planned to observe a scheduled safety audit in 2020. It is probable that Recommendation 2018-02-01 will be closed after that safety audit insight visit.



VIII. Enterprise Protection

Throughout 2019, the ASAP monitored NASA's progress on its Enterprise Protection Program (EPP) and related risk management activities. As was mentioned in our 2018 report, NASA continues to receive pressure from both the Administration (through a May 2017 Presidential Executive Order) and—through numerous audits—the NASA Office of Inspector General (OIG) to broadly account for NASA risk posture across the security enterprise. To NASA's credit, Agency leadership continues to demonstrate growing awareness of the risks and to focus efforts on identifying threats, managing governance structures, and tightening the collaboration links between various risk stakeholders both within and beyond NASA.

The NASA CIO and her team have created a broad set of cybersecurity initiatives, including the development of a NASA Information Technology Strategic Plan and accompanying improvement plans, many of which are already in implementation. According to the objective metrics of the Federal Information Security Modernization Act (FISMA) scorecard, there has already been about a 25% improvement in cybersecurity processes, such as detection of intrusion, responses to intrusion, and recovery from cybersecurity incidents. NASA has increased compliance, mitigated vulnerabilities, improved high-value network segments, and implemented the Office of Cybersecurity Services (OCSS) to define, implement, promote, and optimize a consistent model for enterprise cybersecurity services. All of these activities align with the 2017 Executive Order to improve cybersecurity across the government. This year, the ASAP was very impressed with the CIO and her team, as they appear very action-oriented, motivated, and armed with measurable objectives intended to reduce strategic cybersecurity risk.

The ASAP also had the opportunity to review two new policies related to the EPP. The first policy memorandum, released June 13, 2018, and signed by the Principal Advisor for Enterprise Protection (PAEP), provides Agency-wide updates to the management of Operational Technology (OT), also known as industrial control systems. The second new policy memorandum, dated February 2019 and signed by the Associate Administrator, outlines several new protection requirements for robotic spacecraft, including program direction for command uplink protections and mission data protection, an important step toward reducing risks of mission systems. The intent is that protection requirements related to this policy will be normalized into NASA's standard processes for waivers and deviation approvals by technical authorities, with appropriate risk assessments. The work accomplished in the area of policy for both the CIO and the PAEP teams is to be commended. Looking forward, the implementation of policies and improvement plans through NASA-wide governance, budget alignments, clarity of authorities, and so on will continue to be a watch item for the ASAP in 2020, as it is our intent to better understand how enterprise risk is actually being reduced through these policies and improvement plans.



A continuing area of interest for the ASAP related to enterprise protection is the specific topic of security clearances and whether NASA has positioned clearances in a manner that best reduces risk to the mission enterprise. In 2016, we formulated Recommendation (2016-04-01):

Asset Protection—Security Clearance Policy: The ASAP recommends that NASA make it a matter of policy that priority is given to obtaining the appropriate level of security clearance for all personnel essential to implementing the Enterprise Protection Program, including the appropriate program managers.

At the end of 2018, NASA planned to accomplish a review of all Position Descriptions (required by the Office of Personnel Management [OPM]), including the disposition of security clearances by position. The PAEP provided a very detailed report on the OPM process to the Panel, and the ASAP is satisfied that the *process* for determining security clearance requirements appears to be adequate to meet the intended goals of the recommendation. However, the ASAP would like to see validation of successful *implementation* of this process for its intended purpose. The ASAP has stated that a review of all program manager positions—specifically, their disposition regarding security clearances—would suffice as a “spot check” and give us the confidence that the OPM review process achieves the desired intent. To date, the ASAP has not yet seen this information, and so the above recommendation remains in an “Open” status.

In summary, the ASAP recommendation pertaining to security clearance policy appears to be on the path to resolution. The Panel expects to be able to close this recommendation once it receives metrics confirming that the OPM process to review Position Descriptions does, in fact, ensure that the appropriate NASA personnel with authoritative responsibilities to manage enterprise, corporate, mission, and physical risk have the appropriate clearances.



IX. Summary

Thirteen topic areas of continuing interest to the ASAP are summarized below. They have been broken out to focus attention on individual issues that the Panel feels are worthy of note.

Topics	2019 Assessment
Resource Sufficiency and Continuing Resolutions	Budget inadequacies and uncertainty from partial and full-year Continuing Resolutions add complexity and instability to program management and create potential distractions from safety and mission assurance.
Commercial Crew Flight Readiness	Although significant work remains, both Boeing and SpaceX are making steady progress in preparing to launch astronauts to the ISS.
Human Certification for Artemis	ESD has been designated as the lynchpin of the overall Artemis initiative to meet Space Policy Directive One. Human certification for a significantly more complex ecosystem will require clear, unambiguous integrated risk management processes and practices.
Deep Space Exploration Program Integration	The Artemis Program consists of multiple complex elements, likely to be provided by different providers as delivered “services.” A well-articulated, transparent, and appropriately constructed integration plan is required in order to understand and manage the risk posture for the lunar program.
Human Landing System Development	As NASA considers its acquisition strategy for the human landing system, it must pay special attention to how it will specify, and then later certify, that the vehicle meets the appropriate mission assurance and safety goals.
Continuing Access to Low-Earth Orbit	For the indefinite future, LEO remains the proving ground for technology development, testing, research, human health observation, and crew health risk mitigation. The Panel regards continuing access to LEO to be essential, regardless of the platform in use.
Extravehicular Mobility Units	NASA has invested in internal research and development on the xEMU project and is moving into a prototyping stage. The program path for both replacement EVA suits for use on the ISS and the delivery of lunar space suits to support a 2024 landing is challenging and requires clear definition and the commitment of sufficient resources.
Workforce	NASA’s leadership is advised to deliberately focus on transparent engagement with the workforce that, in undertaking multiple complex, simultaneous developments and operations, is in danger of stress, leading to unwise risk management.
Human Space Flight Mishap Response	With the approach of NASA crewed space flights, it is increasingly urgent that the requirements for a Presidential Commission in the NASA Authorization Act of 2005 be revised to reflect the current environment in order to have flight mishap processes in place in case, and before, the need arises.
Micrometeoroids and Orbital Debris	The risk from MMOD is dominant and increasing, making it essential that meaningful actions be taken to address a burgeoning safety hazard.
Contract Air Services	While there is no question that procuring efforts to provide flight services is efficient and cost-effective under some circumstances, the requirement to provide oversight to ensure safe operations remains with NASA’s flight support personnel. Therefore, it is essential that sufficient personnel with the necessary skills be provided to the appropriate centers to ensure that safety is not compromised.
Aging Aircraft Fleet	Key portions of NASA’s current air fleet are both unique and rapidly approaching an age where they become very difficult to support for safe operations. Obsolete parts, often manufactured by companies that are no longer in business, compromise the best efforts to keep these special aircraft flying safely. NASA needs to develop a strategic plan for the future replacement of the services these aircraft provide to include the acquisition of updated platforms to ensure timely replacement.
Enterprise Protection	NASA has made progress, but the approach toward enterprise risk reduction for physical, corporate, and mission layers still requires considerable maturation to drive significant risk-reducing behaviors across the Enterprise.



APPENDIX A

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

2019 Recommendations¹

2019-04-01

Required Safety and Mission Assurance Technical Excellence Program (STEP) Training for All NASA Personnel: Given the importance of creating a culture of safety across the NASA workforce, and the availability of a resource to promote that goal, the ASAP would like to recommend that NASA adopt an Agency-wide requirement for all employees to complete the STEP Level 1 training course.

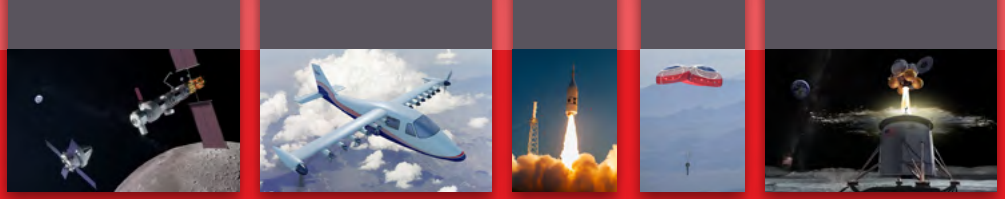
OPEN. NASA response not provided at time of ASAP Annual Report 2019 printing.

2019-02-01

Required Transition to Next-Generation Extravehicular Mobility Units (EMUs): NASA should begin an immediate transition to a next-generation Extra Vehicular Activity (EVA) suit system (EMUs) before the risk to EVA becomes unmanageable.

OPEN NASA responded on 9/11/19, concurring with the recommendation. NASA has, however, made no changes to the current path. ASAP continues to urge that NASA make this a priority.

¹ *Note on colors:* **Red** highlights what the ASAP considers to be a long-standing concern or an issue that has not yet been adequately addressed, or that there is no identified resolution. **Yellow** highlights an important ASAP concern or issue that we are not confident is being addressed adequately, or where a resolution has been identified but does not yet have a defined implementation plan. **Green** indicates a positive aspect or concern that is being adequately addressed but continues to be followed by the Panel. No color indicates that the ASAP has not received a response.



Open Recommendations from Prior Years

2018-04-02

Action to Ensure U.S. Access to the International Space Station (ISS) Given Commercial Crew Program Schedule Risk: Due to the potential for delays in the schedule for the first Commercial Crew Program (CCP) flights with crew, senior NASA leadership should work with the Administration and the Congress to guarantee continuing access to the ISS for U.S. crewmembers until such time that U.S. capability to deliver crew to the ISS is established.

OPEN NASA responded on 3/29/19, concurring with the recommendation. NASA is actively developing, assessing, and implementing options to protect the presence of American crew on the ISS to support the U.S. On-Orbit Segment.

2018-04-01

Required Actions for Crewed Flight Test (CFT) Risk Reduction: NASA should confirm and then clearly communicate the required content and configuration for the upcoming Commercial Crew Program (CCP) test flights, Demo-1 and Orbital Flight Test (OFT); specifically, those items that must be successfully demonstrated prior to the first crewed flights.

OPEN NASA originally responded on 3/29/19, concurring with the recommendation. NASA continues to work with the commercial providers to obtain valuable data from the uncrewed test flights in order to minimize risk to crew for the upcoming crewed test flights: Demo-2 and CFT. CCP certification plans, the results from the series of reviews for each test flight, will culminate in a Certificate of Flight Readiness (CoFR), asserting that the commercial provider has completed all work associated with meeting the applicable requirements, standards (including alternate standards), and hazard reports. Work ongoing into 2020.

2018-02-01 (2017-02-01 Revised)

NASA Safety Assurance Process Scope and Quality: NASA Safety and Mission Assurance should have a coordinated, in-depth system of safety assurance tools and processes to verify effective programmatic safety compliance, system safety practices, safety process function, safety culture, and overall safety posture at all levels of the organization.



OPEN NASA responded on 8/10/18, concurring with the recommendation, which is a revision of ASAP Recommendation 2017-02-01. NASA provided a summary of current and future activities, including deep-dives at selected NASA Centers and documentation of its findings and recommendations for an ongoing performance-based safety and mission success audit process in a State of Capability report. The ASAP has reviewed the report and will attend an audit in 2020 to confirm progress.

2017-01-01

Practice of System Engineering and Integration (SE&I) Principles by Commercial Crew Providers for Transportation Services to the International Space Station (ISS): The Panel recommends that NASA require the commercial crew providers to produce verifiable evidence of the practice of rigorous, disciplined, and sustained SE&I principles in support of the NASA certification and operation of commercial crew transportation services to the ISS.

OPEN NASA responded on 5/22/17, concurring with the recommendation. NASA stated that the Commercial Crew Program (CCP) providers are responsible for ensuring cost-effective system design, realization, operation, and technical management of the systems they are developing to meet a fixed-price contract. Through contract requirements, deliverables, and insight, the CCP is able to verify and/or validate that SE&I principles are followed to assure the proper management of risks, requirements, interfaces, configuration, and technical data throughout the system life cycle. The ASAP is satisfied with what it has learned regarding the SE&I approaches by both companies to date and will continue to monitor the SE&I practices throughout the development and certification process.

2016-04-01

Asset Protection—Security Clearance Policy: NASA should make it a matter of policy that priority is given to obtaining the appropriate level of security clearance for all personnel essential to implementing the Enterprise Protection Program (EPP), including the appropriate program managers.

OPEN NASA responded on 1/17/17, concurring with the recommendation. NASA was establishing clearance requirements within the governance management system of the EPP and is reviewing all positions, descriptions, and compliances accordingly. The Panel was briefed on the EPP in 2018 regarding NASA's improved security clearance procedure and it appears that a fairly robust process exists. NASA will provide a status report in early 2020.



2015-05-02

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

OPEN NASA originally responded on 4/30/16, concurring with the recommendation. The response stated that NASA was reaching out to the Federal Aviation Administration (FAA) and the National Transportation Safety Board (NTSB) to jointly develop viable options to revise the Authorization language with today's systems in mind. NASA provided a follow-up response on 3/20/17 in which they provided the results of NASA's assessment of strategy option in the event of a major malfunction or mishap in the Commercial Crew Program (CCP). The ASAP provided a written response on 9/8/17, followed by subsequent discussions during which the ASAP provided alternate solutions to which NASA provided a third response on 3/15/18. NASA and the Congress are still working to establish a satisfactory process to address the concerns previously articulated. The ASAP believes action is now essential as NASA nears the reestablishment of their human launch capability and urges completion prior to the first crewed CCP launch.

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 safely deorbit the ISS in the event of foreseeable anomalies.

OPEN NASA originally responded on 5/9/12. The ASAP decided the recommendation would stay open until ISS has a timeline for implementing a deorbit plan and the deorbit plan is in place. NASA's Human Exploration and Operation Mission Directorate began working this action when assigned in 2012. There are many aspects to implementing the deorbit plan, including working with International Partners. NASA has received and is continuing to assess information from Roscosmos and is requesting International Partner concurrence with existing documentation. Progress has been slow, but the effort continues to move forward. The Panel is encouraged by the progress being made. The ISS will continue to brief the ASAP on a quarterly basis on the status of this recommendation in 2020.



APPENDIX B

Closure Rationale for Recommendations Closed in 2019

No recommendations were closed in 2019.



APPENDIX C

ASAP Members and Staff

Aerospace Safety Advisory Panel Members



Dr. Patricia Sanders

- Chair, Aerospace Safety Advisory Panel
- Independent Aerospace Consultant
- Former Executive Director of the Missile Defense Agency (MDA)
- Former Director, Test, Systems Engineering, and Evaluation, Office of the Secretary of Defense
- Former Director of Analysis for the U.S. Space Command

Dr. Patricia Sanders is now an independent aerospace consultant after having been a Senior Executive with the Department of Defense (DOD) and retiring from the Federal Government after 34 years of service with experience in the management of complex technical programs, leadership of large and diverse organizations, and development and execution of policy at the DOD level.

Dr. Sanders retired from government service in 2008 as the Executive Director of the Missile Defense Agency (MDA). She was the senior civilian in the Agency responsible for its management and operations, safety and quality control, strategic planning, legislative affairs, external communication, and all issues related to worldwide personnel administration and development. Previously, she had been the System Executive Officer and Deputy Director for Integration of MDA, managing program content, schedule, cost, and technical performance for the Agency's \$9 billion per year program of work.

After teaching for Boise State University and the University of Utah, Dr. Sanders began her national security career with the U.S. Army in Germany in 1974. She progressed through a number of challenging positions including management of several Defense acquisition programs; positions with the Air Force Operational Test Center in space system and aircraft avionics testing; Chief Scientist for



the Command, Control, and Communications Countermeasures Joint Test Force; and Director of Analysis for the U.S. Space Command.

In 1989, Dr. Sanders moved to the National Capital Area to assume the first of a number of staff positions within the Office of the Secretary of Defense, culminating with service as the Director of Test, Systems Engineering, and Evaluation. She joined the missile defense community in 1998 and participated in the establishment of the MDA, was responsible for creating its robust test organization, initiated the Sensors Directorate, and accomplished pioneering work in managing the integration of the Ballistic Missile Defense System.

Dr. Sanders has actively supported professional, academic, and civic organizations, serving on numerous executive boards. She is a Fellow of the American Institute of Aeronautics and Astronautics and has received three Presidential Rank Awards for executive achievements. She was awarded the Allen R. Matthews Award for significant accomplishments in test and evaluation and the AIAA DeFlorez Award for Modeling and Simulation, which recognizes achievements in its aerospace applications.



Mr. David B. West, CSP, ASP, PE, CHMM

- Examinations Director, Board of Certified Safety Professionals (BCSP)
- Former Vice President and Deputy Operation Manager, Science Applications International Corporation
- Chair, G-48 System Safety Committee of SAE International, 2010–2019
- Former Member and Treasurer, BCSP Board of Directors

David B. West is the Examinations Director at the Board of Certified Safety Professionals (BCSP). He is responsible for BCSP activities involving the development, validation, maintenance, and administration of examinations for BCSP certification candidates in the safety, health, and environment field. He previously served as an engineer and system safety subject matter expert for Science Applications International Corporation (SAIC) in positions of increasing responsibility, including vice president, deputy operation manager, and operation-level chief technology officer. During his more than 28 years of service with SAIC, West's work helped ensure the safety of a variety of systems and programs of national importance, including U.S. Army manned and unmanned fixed-wing aircraft and helicopters, military ground vehicle immersive training systems, rocket-launching weapon systems, precision targeting systems, chemical weapons destruction facilities, uranium enrichment and other nuclear operations, super-conducting magnetic energy storage technology, petroleum refining and chemical manufacturing, the Space Station Freedom Program, Space Shuttle microgravity experiments, and the Space Shuttle range safety system. In more recent years, West learned and applied the concepts of software system safety on various projects.

For many years, David West has actively led or supported standards-developing activities for system safety and other specialty engineering disciplines. From 2010 through 2019, West chaired the G-48 System Safety Committee, currently under SAE International. He was one of the authors of the



G-48 Committee’s “Standard Best Practices for System Safety Program Development and Execution,” GEIA-STD-0010, and was the sponsor of its first major revision. From 2017 through 2018, West served as the Vice Chair of SAE International’s Systems Management Council. He also served on the BCSP Board of Directors from 2008 to 2013 and was the Board’s Treasurer from 2012 to 2013.

David West is a fellow member of the International System Safety Society (ISSS) and was awarded its highest honor, the Professional Development Award, in 2013. He was also named the ISSS Manager of the Year in 2010. He was active in Toastmasters International from 2009 through 2017 and has been an invited speaker on system safety topics at several national and international events, including the 1st International Helicopter Safety Symposium in 2005, the FAA 9th Annual Commercial Space Transportation Conference in 2006, the Australian System Safety Conference in 2013, and numerous International System Safety Conferences since 2001.

David West earned a B.S. degree in Nuclear Engineering from the University of Cincinnati. He holds the Certified Safety Professional (CSP), Associate Safety Professional (ASP), and Certified Hazardous Materials Manager (CHMM) credentials, and he is a registered Professional Engineer (PE). He also enjoys astronomy, triathlons, and traveling.



Dr. Richard S. Williams, MD, MPH, FACS

- Director, Three Rivers Health District, Virginia Department of Health
- Senior Aviation Medical Examiner, Federal Aviation Administration
- Former NASA Chief Health and Medical Officer

Dr. Richard S. Williams is a surgeon and aerospace medicine physician who currently serves as Director of the Three Rivers Health District. He leads 10 public health departments serving a 2,000-square-mile rural area in Virginia’s Middle Peninsula and Northern Neck, responsible for public health care and environmental health support to a population of about 140,000. He is also a Federal Aviation Administration Senior Aviation Medical Examiner, performing aviation medical examinations and providing aeromedical consultation services for all classes of airmen. Previously, he served as NASA’s Chief Health and Medical Officer. He spent 27 years in the United States Air Force as a general surgeon, flight surgeon, and medical manager and leader, domestically and in contingency operations abroad.

Dr. Williams reported to NASA Headquarters as an Air Force Colonel in 1998. He served as Director of the Office of Health Affairs and entered the Senior Executive Service as NASA’s Chief Health and Medical Officer in 2002. He led NASA’s health care team through the construction and initial operation of the International Space Station and the final years of the Space Shuttle Program. His responsibilities included leadership, policy, oversight, and advocacy for astronaut health care, NASA employee health care, protection of research subjects, and bioethics. During his 15-year tenure, Dr. Williams led efforts to secure legislative authority for beyond-career astronaut health care, implemented Health and Medical Technical Authority, produced policies on ethics-based risk assessment



for astronaut health and medical exposures during space flight missions, and fostered cooperative efforts between NASA's Human Research Program and health care system to better understand space flight-related health risks and mitigations.

Dr. Williams received a B.S. degree from the College of William and Mary in 1975, an M.D. degree in 1979, and an M.P.H. degree in 1996, both of the latter from Virginia Commonwealth University. He completed general surgery residency at Wright State University in 1984 and aerospace medicine/occupational health residency at the USAF School of Aerospace Medicine in 1998. He is a Fellow of the American College of Surgeons and maintains certification by the American Board of Preventive Medicine in Aerospace Medicine. His awards include the John R. Tamisea Memorial Award, NASA's Space Flight Awareness Award for Safety, the Melbourne C. Boynton Award, the Senior Executive Service Presidential Rank Award, the W. Randolph Lovelace Award, the Forrest M. and Pamela Bird Award, the NASA Exceptional Leadership Medal, and the NASA Distinguished Service Medal. He has contributed to and published numerous articles and book chapters in medical literature.



Lieutenant General Susan J. Helms, USAF (Ret.)

- Independent Consultant and Principal of Orbital Visions, LLC
- Former Commander, 14th Air Force, Air Force Space Command
- Former Commander, Joint Functional Component Command for Space, U.S. Strategic Command
- Former NASA Astronaut

Lieutenant General Susan J. Helms, USAF (Ret.), is currently an independent consultant and the Principal of Orbital Visions, LLC. She is also on a number of boards, including the Board of Trustees for The Aerospace Corporation.

General Helms has almost 36 years of military service in the U.S. Air Force. In her last assignment, she was Commander, 14th Air Force (Air Forces Strategic), Air Force Space Command; and Commander, Joint Functional Component Command for Space, U.S. Strategic Command, Vandenberg Air Force Base, California. As the head of the U.S. Air Force's operational space component, General Helms led more than 20,500 personnel responsible for providing missile warning, space superiority, space situational awareness, satellite operations, space launch, and range operations. As Commander, Joint Functional Component Command for Space, she directed all assigned and attached space forces providing tailored, responsive, local, and global space effects in support of national and combatant commander objectives.

General Helms was commissioned from the U.S. Air Force Academy in 1980 and is a distinguished graduate of the USAF Test Pilot School (Flight Test Engineer Course). She has served as an F-15 and F-16 weapons separation engineer and as a flight test engineer for the CF-18. She has also commanded the 45th Space Wing, Patrick Air Force Base, Cape Canaveral, Florida, and served as the



J5, U.S. Strategic Command. Selected by NASA in January 1990, General Helms became an astronaut in July 1991. On January 13, 1993, then an Air Force Major and a member of the Space Shuttle Endeavour crew, she became the first U.S. military woman in space. She flew on STS-54 (1993), STS-64 (1994), STS-78 (1996), and STS-101 (2000) and served aboard the International Space Station as a member of the Expedition 2 crew (2001). A veteran of five space flights, General Helms has logged 211 days in space, including a spacewalk of 8 hours and 56 minutes, a world record.



Dr. Donald P. McErlean

- Senior Aerospace Engineering Consultant
- Faculty member, Baylor University, Waco, Texas
- Former Engineering Fellow/Research Scientist, L3 Technologies
- Former Director, Aerodynamics and Mechanical Engineering and Industrial Design, L3 Technologies, Platform Integration Division
- Former Chief Engineer, Naval Aviation, Naval Air Systems Command

Dr. McErlean is currently a senior aerospace engineering consultant. A member of NASA's Aerospace Safety Advisory Panel, he specializes in airworthiness, certification, and airframe engineering and safety. He is also a member of the faculty of Baylor University, College of Engineering and Computer Science.

From 2007 until 2016, Dr. McErlean was employed by L3 Technologies, where he served as an Engineering Fellow and Research Scientist of the Platform Integration Division of the Aerospace Systems Group. He was responsible for the management of research and development, technical assessment of new business opportunities, and development of technical personnel and policy strategies in support of the division. He also held organizational assignments as Director of Aerodynamics and Director of Mechanical and Industrial Design.

Dr. McErlean left Federal service in 2005 following a career of more than 35 years. Upon retirement, he subsequently worked as a private consultant and then joined the staff of L3 Technologies (now L3 Harris Technologies). From 1966 to 1994, Dr. McErlean served in the U.S. Air Force Reserve, retiring at the rank of Lieutenant Colonel. From 1970 until 1987, he served in various technical and management positions with Air Force Systems Command (AFSC) both as an active duty Air Force officer and a civilian engineer. Leaving AFSC in 1987, he was appointed a member of the Federal Senior Executive Service (SES) and served as the Director of Air Vehicle and Crew Systems Technology at the Naval Air Development Center. In 1994, he served in a joint assignment when the Navy and Air Force jointly selected Dr. McErlean to serve as Technical Director for the Joint Strike Fighter Program. In 1996, he joined the engineering management team of the Naval Air Systems Command and served as Head of the Air Vehicle Engineering Department, Executive Director for Command-Wide Test and Evaluation, and Executive Director of the Naval Air Warfare Center Aircraft Division. He subsequently served as the Deputy Assistant Commander for Logistics and Fleet Support and oversaw the Naval Aviation buildup for operations in Iraq and Afghanistan. In his



final position prior to retirement from Federal service, Dr. McErlean was appointed Deputy Assistant Commander for Research and Engineering (Naval Aviation's civilian Chief Engineer).

Dr. McErlean is the recipient of several SES awards for exceptional performance as well as the Presidential Rank Award from Presidents George W. Bush and William J. Clinton. In 1987, he received the Exceptional Civilian Performance Medal from the Air Force. He is the recipient of the Navy Superior Civilian Performance Medal and the Navy Distinguished Civilian Performance Medal, the Navy's highest civilian award for performance.

Dr. McErlean received his Ph.D. in aerospace engineering (fluid dynamics major, applied mathematics minor) from Rutgers University and an M.S.M. from the Sloan School of Management at the Massachusetts Institute of Technology.



Dr. George C. Nield

- Independent Aerospace Industry Consultant
- Former Associate Administrator for Commercial Space Transportation, Federal Aviation Administration (FAA)
- Former Manager of the Flight Integration Office at NASA Johnson Space Center
- Flight Test Engineering Graduate of the U.S. Air Force (USAF) Test Pilot School

Dr. George C. Nield, currently an Independent Aerospace Industry Consultant, was formerly the Associate Administrator for Commercial Space Transportation at the FAA. Under his leadership, the office had the mission to ensure public safety during commercial launch and reentry activities, as well as to encourage, facilitate, and promote commercial space transportation. Dr. Nield has over 35 years of aerospace experience with the Air Force, at NASA, and in private industry.

Prior to joining the FAA, Dr. Nield was a Senior Scientist for the Advanced Programs Group at Orbital Sciences Corporation, where he worked on the Space Transportation Architecture Study, the 2nd Generation Reusable Launch Vehicle Program, and the Orbital Space Plane. Previously, he served as Manager of the Flight Integration Office for the Space Shuttle Program at NASA Johnson Space Center, and he later worked on both the Shuttle/Mir Program and the International Space Station Program. While on active duty with the Air Force, he was an assistant professor and research director at the USAF Academy. As a flight test engineer for the Air Force Flight Test Center at Edwards Air Force Base, he supported the A-7 DIGITAC program, the YC-14 Advanced Medium STOL Transport, and the Space Shuttle Approach and Landing Tests. He also served as an astronautical engineer with the Space and Missile Systems Organization, identifying technology requirements for military space vehicles.

A graduate of the USAF Academy, he holds an M.S. and Ph.D. in aeronautics and astronautics from Stanford University and an MBA from George Washington University. He is also a flight test engineering graduate of the USAF Test Pilot School. Dr. Nield is a registered Professional Engineer and a Fellow of the American Institute of Aeronautics and Astronautics.



Captain Christopher Saindon, USN (Ret.)

- First Officer, JetBlue Airways
- Former Director of the U.S. Naval School of Aviation Safety and Flight Instructor at Training Squadron TEN
- Former Director of Aviation Safety Programs at the U.S. Naval Safety Center
- Former Navigator, USS Enterprise (CVN-65)
- Former Navigator, USS Harry S. Truman (CVN-75)
- Former Commanding Officer, Patrol Squadron FORTY

Captain Saindon is currently a First Officer with JetBlue Airways. He retired from the Navy in February 2017 after more than 27 years of naval service. Immediately prior to retiring from active duty, Captain Saindon served as the Director of the U.S. Naval School of Aviation Safety at NAS Pensacola and a flight instructor at Training Squadron TEN from May 2015 through February 2017.

Captain Saindon hails from Orlando, Florida, and attended the University of Central Florida, where he earned a B.S. in psychology and statistics in August 1989. Captain Saindon was selected to attend U.S. Navy Aviation Officer Candidate School at Naval Air Station Pensacola, Florida, and was commissioned as an Ensign in April of 1990. He completed Navy flight training at NAS Whiting Field and NAS Corpus Christi, earning his Navy “Wings of Gold” in September 1991.

Captain Saindon’s Navy operational flying assignments included numerous squadron tours flying the Lockheed P-3C Orion Maritime Patrol and Reconnaissance aircraft on missions around the globe. He attained every available qualification in the P-3C Orion, including Tactical Mission Commander, Instructor Pilot, and Fleet Evaluation Pilot, and he was a squadron Aviation Safety Officer. Captain Saindon served as the Commanding Officer of Patrol Squadron FORTY from 2007 through 2009.

In addition to his aviation assignments, Captain Saindon served as Ship’s Navigator aboard both the USS Enterprise (CVN-65) and USS Harry S. Truman (CVN-75) from 2009 to 2013, where he qualified as Command Duty Officer Underway and completed three separate work-up and training cycles, as well as a deployment to the Middle East and the Mediterranean.

Captain Saindon’s other Navy assignments include Patrol Squadron THIRTY as a P-3 Fleet Replacement Squadron Instructor Pilot and Fleet Standardization Evaluator; Naval Personnel Command as the Aircraft Carrier Placement Officer; Naval War College, where he earned a master’s degree in national security strategy and policy; and Naval Safety Center as Director, Aviation Safety Programs.

Captain Saindon qualified as a Federal Aviation Safety Officer and has logged more than 5,500 flight hours in numerous military and civilian aircraft flights.



Dr. Sandra H. Magnus

- Deputy Director for Engineering in the Office of the Undersecretary for Research and Engineering, Department of Defense (DOD)
- Former Executive Director of the American Institute of Aeronautics and Astronautics (AIAA)
- Former Deputy Chief, NASA Astronaut Office, Johnson Space Center
- Former NASA Astronaut

Dr. Sandra H. “Sandy” Magnus is the Deputy Director for Engineering in the Office of the Undersecretary for Research and Engineering in DOD. Before joining DOD, she served as the Executive Director of the AIAA, the world’s largest technical society dedicated to the global aerospace profession.

Born and raised in Belleville, Illinois, Dr. Magnus attended the Missouri University of Science and Technology, graduating in 1986 with a degree in physics and in 1990 with a master’s degree in electrical engineering. She received a Ph.D. from the School of Materials Science and Engineering at Georgia Tech in 1996.

Selected to the NASA Astronaut Corps in April 1996, Dr. Magnus flew in space on the STS-112 Shuttle mission in 2002 and on the final Shuttle flight, STS-135, in 2011. In addition, she flew to the International Space Station on STS-126 in November 2008, served as flight engineer and science officer on Expedition 18, and returned home on STS-119 after four and a half months on board. She served at NASA Headquarters in the Exploration Systems Mission Directorate. Her last duty at NASA, after STS-135, was as the deputy chief of the Astronaut Office.

While at NASA, Dr. Magnus worked extensively with the international community, including the European Space Agency (ESA) and the Japan Aerospace Exploration Agency (JAXA), as well as with Brazil on facility-type payloads. She also spent time in Russia developing and integrating operational products and procedures for the International Space Station.

Before joining NASA, Dr. Magnus worked for McDonnell Douglas Aircraft Company from 1986 through 1991 as a stealth engineer. While at McDonnell Douglas, she worked on internal research and development and on the Navy’s A-12 Attack Aircraft program, studying the effectiveness of radar signature reduction techniques.

Dr. Magnus has received numerous awards, including the NASA Space Flight Medal, the NASA Distinguished Service Medal, the NASA Exceptional Service Medal, and the 40 at 40 Award (given to former collegiate women athletes to recognize the impact of Title IX).



Mr. Paul Sean Hill

- Independent Consultant, Author, Speaker, and Principal of Atlas Executive, LLC
- Former Director of Mission Operations, NASA Johnson Space Center
- Former Shuttle and ISS Flight Director

Paul Sean Hill is an author and speaker focused on the leadership principles that are critical in creating and leading high-performing teams in any industry. During his 25 years at NASA, Paul first developed space station construction techniques and then led flights from Mission Control as a Space Shuttle and International Space Station Flight Director. He supported 24 missions as a Flight Director from 1996 through 2005, culminating as the Lead Shuttle Flight Director for the return-to-flight on STS-114 after the Columbia accident.

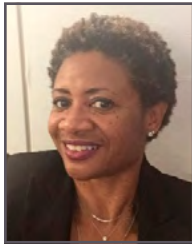
After a series of senior leadership positions, Paul served as the Director of Mission Operations for human space flight from 2007 through 2014, responsible for all aspects of mission planning, flight controller and astronaut training, and Mission Control. He is credited with revolutionizing the leadership culture, dramatically reducing costs, and increasing capability, all while still conducting missions in space.

Before his work with NASA, Paul served in the United States Air Force in military satellite operations. He earned his bachelor's degree and Master of Science degrees in aerospace engineering from Texas A&M University in 1984 and 1985, respectively, and was a member of the Corps of Cadets.

His professional awards include the Presidential Rank Award of Meritorious Executive, two NASA Outstanding Leadership Medals, the NASA Distinguished Service Medal, the NASA Exceptional Service Medal, the Rotary National Award for Space Achievement—Stellar Award, and selection as one of the Marshall Goldsmith 100 Coaches.



Aerospace Safety Advisory Panel Staff Members



Ms. Carol Hamilton, ASAP Executive Director

Ms. Carol Hamilton, Executive Director of the ASAP since 2015, has specialized in system safety engineering for more than 25 years. Her career also includes experience in systems engineering, systems verification, and system test engineering for both NASA space systems and the Department of Defense systems. During her time at Goddard Space Flight Center (GSFC) from 1991 through 2015, Hamilton contributed to more than 15 space flight missions, serving as a Senior System Safety Engineer for Hernandez Engineering for 8 crewed Space Shuttle missions and later as the Project Safety Manager for 14 uncrewed space missions. During her NASA career, she has been an instructor for the NASA Safety Training Center and has served on a number of NASA mishap investigation boards.



Ms. Lisa Hackley, ASAP Administrative Officer

Ms. Lisa Hackley has worked at NASA Headquarters for over 29 years providing administrative support for numerous mission directorates and divisions, including the Office of Space Flight (now Human Operations and Exploration), the Office of Life and Microgravity Science and Applications (now Space Life and Physical Sciences), the Office of Biological and Physical Research, and the Office of International and Interagency Relations (OIIR). Prior to joining the Advisory Committee Management Division (ACMD) as the ASAP Administrative Officer in May 2019, Hackley worked in OIIR's Export Control and Interagency Liaison division for 15 years, including a voluntary secondment to FEMA in late 2017 to assist with the hurricane relief efforts.



Ms. Kerry Leeman, ASAP Annual Report Editor

Ms. Kerry Leeman received B.A. degrees in philosophy and technical writing. With 22 years as a technical writing professional spanning the aviation, aerospace, petrochemical, and biomedical industries, she joined the ASAP as technical report writer in 2019. Her prior experience with NASA includes technical writing for the Constellation Space Suit Program and demonstrating the extravehicular mobility unit space suit to Houston-area students. She is currently a technical writing consultant for a regulatory and energy transmission services agency in Austin, Texas.



AEROSPACE SAFETY ADVISORY PANEL

Dr. Patricia A. Sanders, Chair

Lieutenant General Susan J. Helms, USAF (Ret.)

Mr. Paul S. Hill

Dr. Sandra H. Magnus

Dr. Donald P. McErlean

Dr. George C. Nield

Captain Christopher M. Saindon, USN (Ret.)

Mr. David B. West

Dr. Richard S. Williams

