National Aeronautics and Space Administration

Aerospace Safety Advisory Panel

Annual Report

2024

NASA Aerospace Safety Advisory Panel
National Aeronautics and Space Administration
Washington, DC 20546

January 25, 2025

The Honorable Janet Petro
Acting Administrator
National Aeronautics and Space Administration
Washington, DC 20546

Dear Ms. Petro:

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 2024 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 2024 fact-finding and quarterly public meetings; direct observations of NASA operations and decision-making; discussions with NASA management, employees, and contractors; and the Panel members' past experiences.

This report reflects the Panel's strong emphasis on strategic-level aspects of NASA leadership, risk management, and safety culture, a primary focus over the past two years, while also giving attention to the tactical level of technical execution. We believe that the principles and processes the Agency employs to evaluate and make decisions, manage programs, and communicate to its workforce have a direct and consequential impact on safety and mission assurance.

Over the past year, NASA has continued to make meaningful progress towards meeting the intent of the broad-ranging recommendations the Panel has made over the last several years. We believe that the Agency's careful attention to vision, governance, and program management is vital to the safe execution of NASA's complex and critical national mission. The Panel acknowledges that the recommendations are ambitious and achieving them demands considerable time and effort. That said, as observations in this report reveal, NASA has made impressive progress. Challenges remain, however, and are highlighted in this report.

Of note, this report documents significant safety observations for both the Moon to Mars Program and the current International Space Station operations in low-Earth orbit (LEO). In addition, the Panel notes that there are considerable risk-related issues surrounding NASA's planned transition to Commercial LEO Destinations, some of which are not wholly within NASA's control. This report also touches on relevant areas of human health and medicine in space and the impact of budget constraints and uncertainty on safety.

I submit the ASAP Annual Report for 2024 with respect and appreciation.

Sincerely,

Lieutenant General Susan J. Helms, USAF (Ret.)
Chair, Aerospace Safety Advisory Panel

Enclosure

NASA Aerospace Safety Advisory Panel
National Aeronautics and Space Administration
Washington, DC 20546

January 25, 2025

The Honorable JD Vance
President of the Senate
Washington, DC 20510

Dear Mr. Vice President:

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NASA Aerospace Safety Advisory Panel
National Aeronautics and Space Administration
Washington, DC 20546

January 25, 2025

The Honorable Mike Johnson
Speaker
United States House of Representatives
Washington, DC 20515

Dear Mr. Speaker:

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Contents

I. Preface

Congress established the Aerospace Safety Advisory Panel (ASAP or Panel) in 1968 to provide advice and make recommendations to the National Aeronautics and Space Administration (NASA) Administrator and Congress on safety matters. The Panel holds quarterly fact-finding and public meetings and visits to NASA Field Centers and other related sites. It reviews safety studies, operation plans, and management activities, and advises the NASA Administrator and Congress on risks and hazards related to proposed or existing facilities and operations, safety standards and reporting, safety and mission assurance aspects of ongoing and proposed programs, and managerial and organizational culture issues related to safety. Although the Panel may perform other duties and tasks as requested by either the NASA Administrator or Congress, the ASAP members normally do not engage in specialized studies or detailed technical analyses.

The issues, concerns, and recommendations articulated in this report are based on fact-finding and quarterly public meetings; insight visits and meetings; direct observations of NASA operations and decision-making; and discussions with NASA management, employees, and contractors during 2024. Though the particular issues on which the ASAP focuses and the findings it reports often address specific technical concerns, the ASAP also surveils organizational culture, governance, program formulation, and resources as they affect safety and the agency's management of risk more generally. Ultimately, the ASAP may offer recommendations as formal advice to the Agency and Congress.

The ASAP's annual report synthesizes observations and deliberations arising from its work over the year. For reference, Appendix A contains the Panel's open recommendations from prior years. The recommendations the ASAP closed in 2024 are included in Appendix B.

II. Introduction

The ASAP's charter directs the Panel to evaluate safety performance and provide advice about management and culture related to safety. Because safety must remain an overriding priority for NASA, safety culture is at the core of the Panel's work. Safety culture concerns values, beliefs, behaviors, and norms specifically related to risk. Culture is a social construct, a system of shared values and beliefs that give rise to a set of consistent habits and patterns of behavior. It is shaped by incentives and sanctions, and it persists through choices and actions that an organization has decided are acceptable ways to be and act. Safety culture is not a phenomenon that exists in isolation but is an integral part of organizational culture. Thus, the question of interest to the Panel is not what NASA's safety culture is per se, but whether NASA's culture has the right safety focus—that is, whether NASA's shared values, perceived expectations, and accepted behaviors do, in fact, support safety in practice. For example, while "organizational silence" (a phenomenon that occurs when employees cannot or will not speak up about problems) might be a modest hindrance to effectiveness in other industries, it would be devastating at NASA, where protecting the lives of astronauts and the public absolutely demands frank and open debate about safety risks.

The Panel works to help NASA foster a culture that embraces a healthy fear of failure and avoids "blind spots" by asking hard questions about risk. In NASA's present culture, overt reprisal or retaliation for expressing a

safety concern is exceedingly unlikely, and the Panel has not witnessed or heard evidence of such occurring. But, as the Columbia and Challenger accident investigations revealed, insidious norms can erode safety in subtle ways that accumulate to tragic failure. Thus, through our inquiries and observations, we attempt to understand what behaviors are valued, tolerated, modeled and rewarded in support of (or adverse to) safety. During high-stress operations, sometimes with conditions of great uncertainty, we also watch for behaviors that either support or obstruct healthy engagement related to risk, the management of dissent, and whether the workforce can freely express safety concerns, either publicly or candidly, without fear of a dismissive, disdainful, or disrespectful response.

While we do scrutinize policies, procedures, and programs specifically related to risk assessment and decision-making—and NASA has some very excellent programs—much of the Panel's attention to the cultural dimensions of safety are embedded throughout our fact-finding engagements with pivotal leaders and prominent stakeholders, such as the Astronaut Office. In every interaction with NASA, regardless of topic, we routinely ask how NASA discusses, assesses, and reconciles matters related to risk. And, in fact, the Agency's leaders naturally volunteer their perspective on safety and risk as widely held "top-of-mind" concerns. Often, knowledgeable managers offer new avenues of inquiry about risk and safety. Consequently, over the past year, candid conversations with many key leaders have allowed the Panel to acquire and maintain awareness of salient safety issues and to assess the organizational cultural context of those conversations.

Grounded in this awareness, this year's report reflects the Panel's recent focal emphasis on the strategic dimensions of NASA's risk management and safety culture in today's environment of space commercialization. Three years ago, recognizing that NASA was poised at a strategic inflection point, our 2021 Annual Report highlighted the need for the Agency to evaluate its approach to safety and technical risk and to evolve its role, responsibilities, and relationships with private-sector and international partners to align with new realities. Even as the roles of commercial providers and international partners in human space flight architectures and operations expand, future exploration missions are, by national policy and law, NASA missions. Thus, the Agency is and will remain accountable for safety, mission assurance, and integrated risk management. Today's complex relationships, evolving business processes, and workforce dynamics both within and beyond NASA's borders have profound implications for risk and strain assessment and management systems, making vigilance about safety all the more crucial.

To contend with these challenges and prompt NASA to revise its risk management capabilities for a new era, the Panel made three broad recommendations with respect to the Agency's strategic vision, approach to governance, and integrated program management. In 2024, we observed that NASA has made substantial progress towards meeting the intent of these recommendations. The standup of the Moon to Mars (M2M) Program Office has aligned the disparate Artemis Program Offices under one coherent hierarchy, enabled more effective execution and risk management, and streamlined communications with industry. The broad, collaborative "NASA 2040" effort is building Agencywide consensus on NASA's strategic future and already features initial implementation frameworks. This initiative can serve very usefully as something of a "North Star," providing an enduring purpose to guide Agency priorities and against which to make choices over the next dozen or more years.

In short, we commend NASA's impressive advancement over the past three years. At the same time, we reiterate that the Agency's ability to effectively manage complicated and deeply integrated safety risks within its aerospace portfolio heavily depends on several factors, most especially:

- The strength of its governance processes to evaluate and mitigate risk and direct the necessary strategic resource decisions,
- The vital guidance necessary to build and retain a viable workforce with the knowledge and skills to meet future challenges,
- An effective, unambiguous organizational construct designed to effectively manage highly complex space flight campaigns of extraordinary risk, and
- An integrated and balanced acquisition and development strategy that ensures the Agency retains the necessary controls over safety-related development decisions, risk management, and mission assurance.

The Panel looks to see substantive operationalization and institutionalization of these efforts in 2025. Of particular concern are the risks surrounding the development, integration, and execution of the Artemis campaign. NASA's mandate for deep space exploration to Mars and beyond is supremely challenging and fraught with uncertainty. A critical steppingstone in the development of human interplanetary travel capabilities and space hardware—and ultimately safe operations and overall mission success—is the safe return to the Moon. The Moon offers both the opportunity to gain experience operating on a planetary surface and a nearby test bed with an extreme environment akin to Mars. Yet, NASA will face a myriad of daunting budgetary, industrial, geopolitical, technical, and health and medical constraints and challenges as it both executes the Artemis campaign and maintains the Nation's presence in low-Earth orbit (LEO) throughout the coming decade.

NASA, by its very nature as a space agency, exists in an environment pervaded by risk—the dynamism of emerging commercial space endeavors, the aging International Space Station (ISS) and its future replacement systems, and the ambitious Artemis program are a few striking sources of technical risk. There is also risk generated by strategic decisions, operational requirements, acquisitions approaches, resource allocations, the actions and incentives of commercial and international partners, and a multitude of other dimensions of NASA's mandate, responsibilities, and daily work. Identifying and assessing these risks; recognizing how they interact; understanding how they affect safety; and managing them systematically, deliberately, and exhaustively is no small challenge.

This report presents our assessment of NASA's progress and readiness to contend with this reality. We present our assessment of the Artemis program and the Commercial Crew Program (CCP), with a focus on the recent Starliner Crew Flight Test mission, as well as our growing concerns about the ISS. We present our view of NASA's plans for a viable, persistent presence in LEO after the decommissioning of the ISS. Finally, we offer the Panel's perspective on solutions Congress can influence and risks it can mitigate.

III. Continued Focus: Strategic Vision and Agency Governance

In its 2021 Annual Report, the ASAP made the following recommendations:

2021-05-01 Recommendation: NASA should develop a strategic vision for the future of space exploration and operations that encompasses at least the next twenty years, including potential alternative scenarios, that is driven by how the Agency is going to understand and manage risk in the more complex environment in which it will be operating.

- The vision should describe the role that NASA intends to play during that period and how it plans to engage with both commercial and international partners.
- NASA should assess the workforce, including the number, types, skills, experience, and responsibilities that will be required, and the infrastructure facility requirements, with a plan for managing changes needed to meet those requirements.
- NASA should also propose general criteria for evaluating "make, manage, or buy" decisions on future programs or projects.
- All aspects of the strategic vision and its implementation should be clearly and unambiguously communicated throughout the Agency.

2021-05-02 Recommendation: As a part of an overall risk management approach and in order to develop and execute its strategic vision for the future of space exploration, NASA should establish and provide leadership through a "board of directors" that includes the Center Directors and other key officials, with the emphasis on providing benefit to the Agency's mission as a cohesive whole, and not to the individual components of the Agency. The Board should act to identify the strategic risks and obstacles that NASA may encounter in executing its mission, evaluate Agency-level mitigation approaches, and align the efforts of all Centers to ensure desired outcomes.

These recommendations aimed to encourage NASA to position itself intentionally in the realm of space exploration, with careful attention to developing and operationalizing a strategy for how the Agency would manage risk and safety in the complex environment of a changing industrial base and international landscape. The Panel viewed this undertaking as critical for NASA and the Nation in the future of space exploration and operations, including NASA's ability to explicitly consider and appropriately address its own inherent responsibilities to manage risk and safety in the arena of human space flight.

Responsive to these recommendations, NASA has established NASA 2040, which it describes as "an agency strategic initiative that accelerates and aligns planning for the necessary workforce, infrastructure and technology capabilities necessary to meet the bold mission requirements of tomorrow." NASA 2040 is supported by a commensurate governance structure to drive consensus for execution and management of the strategy. Notable highlights of the NASA 2040 work-to-date include:

- The NASA executive leadership team is collaboratively vetting strategic choices, making decisions, and assigning tasks for execution throughout the Agency.
- For alignment and accountability purposes, the Agency has embedded NASA 2040 objectives into their executives' annual performance plans and increased weighting of performance in the Business Acumen and Leading Change objectives. It has also embedded key personnel at each Center who are members of the 2040 team responsible for execution.
- NASA's future role with respect to and relationship with industry and international partners has been embedded in the Agency strategy, using a "Make, Manage or Buy" decision paradigm which has been promulgated to the Centers for workforce, infrastructure, and budgetary alignment to Agency priorities.
- NASA has established an Agency Infrastructure Master Plan aligned to its strategic priorities, a first for the Agency. The plan identifies critical infrastructure needed for the future, existing infrastructure requiring investment, and infrastructure divestment opportunities. As a result of this effort, new budget models for funding infrastructure, including maintenance requirements, are under consideration, and Legislative Proposals have been identified and proposed to support NASA's future infrastructure needs. The team has developed key metrics to track progress.
- To address workforce requirements, NASA has developed an employee value proposition to drive strategic talent recruitment, development, motivation, and retention. The intent is to use the value proposition to shape the future workforce needed to meet NASA technical needs and create a productive workplace environment that will benefit both employees and the agency.
- The NASA 2040 initiative has strategically influenced technology planning. As an example of a tangible outcome of the NASA 2040 initiative, the NASA Chief Information Officer (CIO) led a data center needs assessment based on the Agency's future vision and strategic priorities rather than a single program or Center's needs.
- Safety has been an overriding priority for NASA and is a core value at the forefront of each of the NASA 2040 documents.

The Panel finds that NASA has made great strides against the 2021 recommendations. The Agency has established a governance structure for decision-making, alignment, and accountability that includes Headquarters leaders and Center Directors. Likewise, the NASA 2040 effort is essential, foundational, and has provided clear purpose to ground risk management and investment decisions. Led by the NASA 2040 team, NASA has made tremendous progress forming and normalizing an Agencywide implementation approach to enact the changes necessary to support its vision and objectives. Specific, tangible actions to address critical risks with respect to workforce, infrastructure, and budget are becoming evident. Next, NASA must fully operationalize the strategy through execution of tactical implementation plans across key lines of effort aligned with NASA Headquarters and across the NASA Centers and paired with an explicit, deliberate effort to hold Center leaders responsible for execution. So far, most implementation planning and the governance structure are still nascent, and the Panel urges NASA to maintain its priority and momentum on the 2040 effort.

IV. Continued Focus: Moon to Mars Management

Over the last several years, NASA has implemented important initiatives to improve safety, strengthen risk management, and clarify accountability within the Artemis campaign. NASA has established a single office to manage and execute the program. The program office has, in turn, defined a long-term architecture and top-level requirements for the Artemis mission series and matured its risk management efforts to enable both consideration of individual subsystem risks and aggregation of risks for each mission. These efforts have gone far toward establishing a rigorous safety and risk management focus as a cornerstone for the Artemis campaign. These advances in program definition and organizational structure were necessary and are significant, but there remain important areas of concern for the Panel, particularly with respect to the Artemis II and III missions.

A. Artemis II

The Artemis II flight test succeeds the 2022 uncrewed Artemis I test to demonstrate a range of capabilities needed on deep space missions. It will be the first mission with crew aboard the Space Launch System (SLS) rocket and Orion spacecraft. Throughout 2024, the Agency continued progress towards the execution of the Artemis II mission, including:

- Training of the Artemis II crew;
- Delivery, mating/stacking, and testing of the various Artemis II subsections; and
- Resolution of most Artemis I off-nominal issues.

During 2024, the Orion Program continued proactively investigating the heat shield spalling and char loss that occurred during Artemis I entry on December 11, 2022, with a focus on understanding the physics of the failure and identifying corrective actions. In April 2024, the M2M Program chartered an Independent Review Team (IRT) to review the available data and NASA investigation, assess NASA's conclusions, and make recommendations to the Orion Program, the M2M Control Board, and NASA's executive leadership.[1]

[1] Of note, the Chair of the IRT was also a member of the ASAP, serving NASA in an independent capacity separate from Panel responsibilities.

By October, NASA had determined probable cause and, in a December 5, 2024, press conference, the Agency summarized the cause, corrective actions for future heat shield assemblies, and entry trajectory changes that can enable Artemis II to fly with the existing heat shield. NASA also announced a new Artemis II launch date no earlier than April 2026. The ASAP has not yet reviewed the engineering details of this work and the related risk assessments with NASA. This will be a Panel focus early in 2025.

B. Artemis III

Artemis III is planned as a crewed surface landing and exploration of the lunar south pole region. The Panel remains very concerned that, on the current schedule and with the current technical readiness level of some segments of the architecture, the Artemis III mission is oversubscribed. Specifically, as the Panel discussed in its 2023 Annual Report (summarized in Figure 1), the aggregated risk associated with accomplishing so many "first-time" milestones, including several critical prerequisite demonstrations, may be too high.

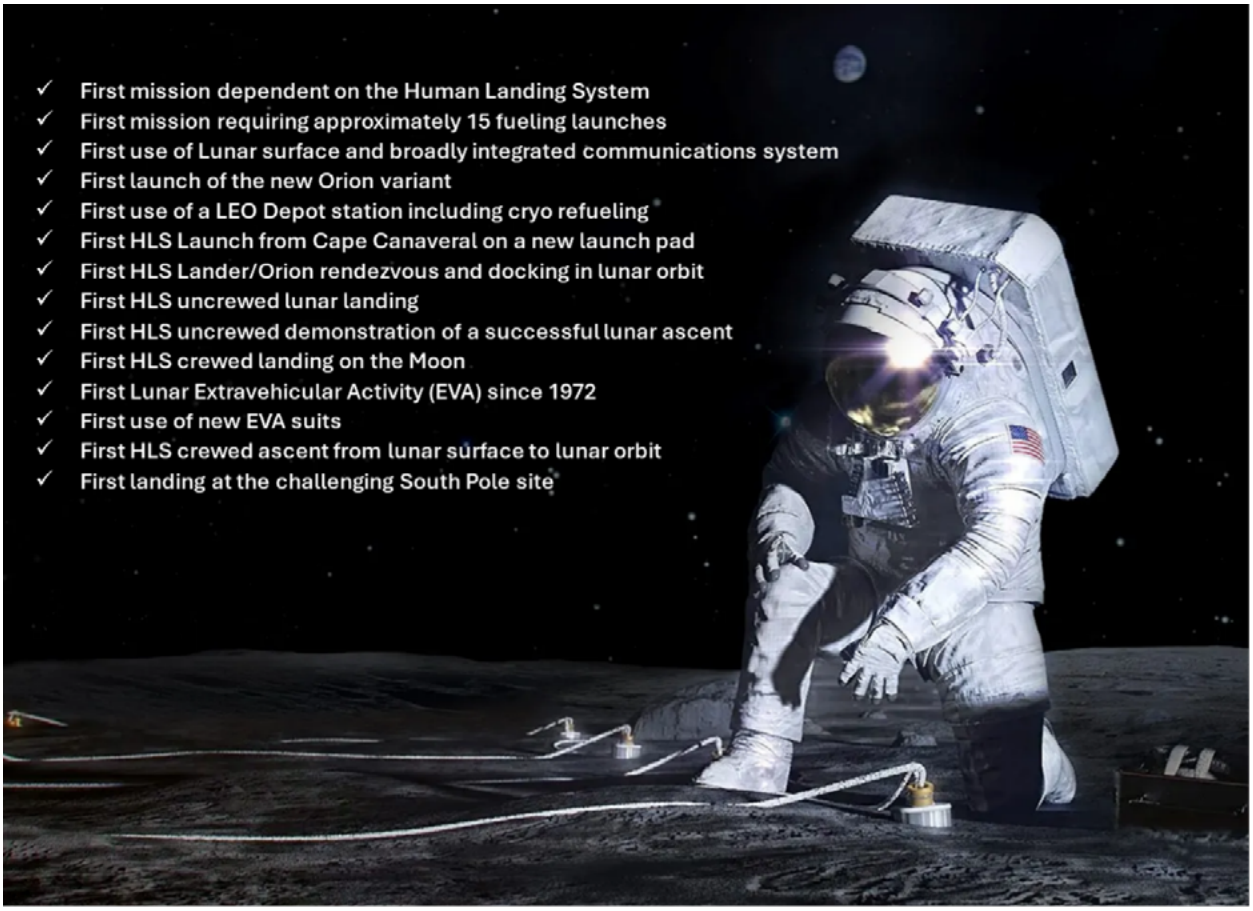

Figure 1. First-time milestones for the Artemis III mission.

There are several key risks associated with the Artemis III mission. Landing at the South Pole is a salient one. To address this, NASA has conducted engineering simulations and studies to understand the risks associated with various landing sites and has selected what it deems optimum in that region. To mitigate risks associated with the South Pole landing site (such as solar coverage, communications, and ascent/descent trajectory), NASA directed engineering design changes to the Human Landing System (HLS) service contract.

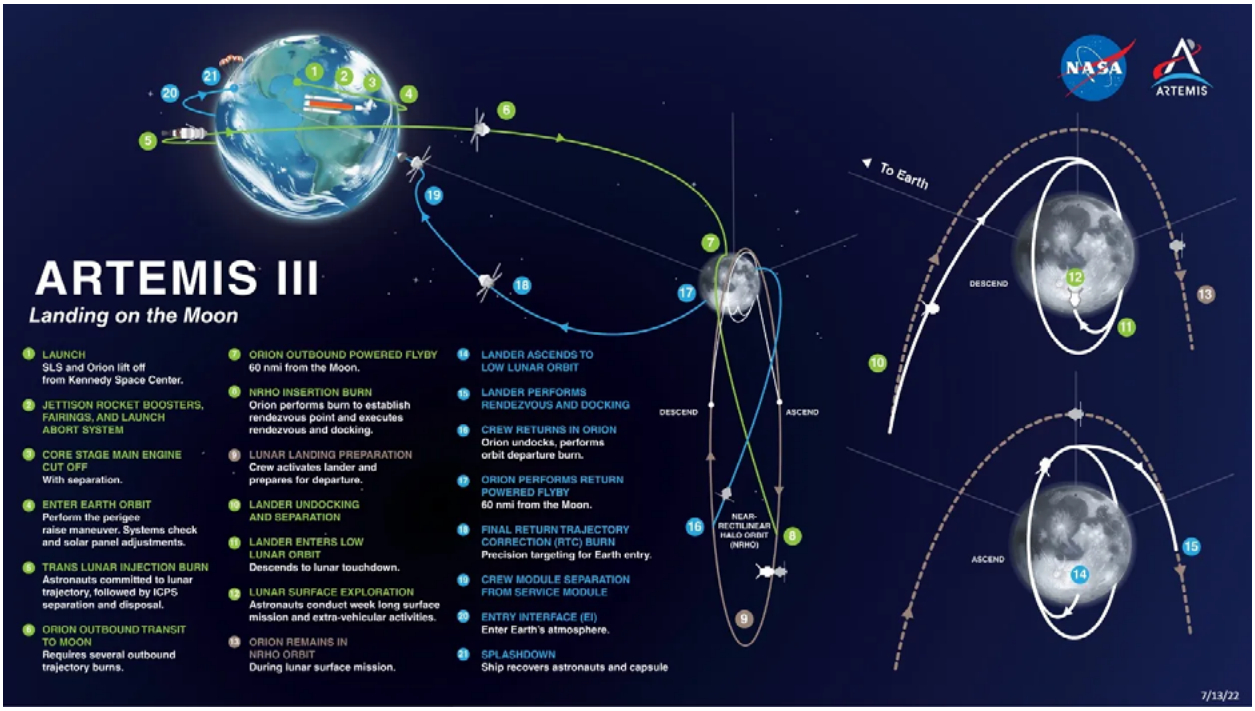

Figure 2. Summary of the Artemis III mission plan.

Many other Artemis III mission risks are associated with HLS, as one critical architectural component in development. The development of HLS and associated flight tests have progressed well. The program has made notable progress since contract award in 2021, and the contractor continues to mature the HLS design and reduce safety and technical risks after every flight test, incorporating engineering findings and lessons quickly and efficiently into the next design iteration. Key engineering objectives successfully demonstrated to date include:

- Launch, high-altitude flight, and reentry of the vehicle,
- Hot-stage separation,
- Performing a flip maneuver in space, and
- Booster return and catch on launch gantry.

There remain extraordinary challenges, however, including the demonstration of a complex operational concept and the validation of vehicle safety for crewed flight. In addition, the delivery of fuel to orbit, cryogenic refueling, and long-duration storage in space; HLS and Orion mating; and HLS successful descent to and ascent from the lunar surface are just a sample of critical test objectives that must be successfully demonstrated to ensure risks are managed appropriately prior to a crewed mission. Given the baseline test schedule for HLS, 2025 will be an eventful and impactful year for the M2M program.

Another essential component for Artemis III is the development of a spacesuit, the Exploration Extravehicular Mobility Unit (xEMU), to support safe lunar operations for the astronauts. An extravehicular spacesuit is a complex unit encompassing all human life-support requirements necessary to operate on the lunar surface. The xEMU contract was awarded in 2023, and development began immediately. Although the xEMU reference design package is NASA-owned and -developed, and has been provided to the developer for design, development, and production, the remaining 18-month delivery schedule of a final product that is completely tested, verified, and proven safe for astronauts on the lunar surface, especially in the harsh conditions of the South Pole, will be a difficult challenge. The Panel is very concerned about the aggressiveness of the schedule, especially considering all other highly specialized work the NASA team must align and integrate for the Artemis III mission.

Both the HLS and the xEMU are critical path items for the successful execution of the Artemis III mission. Because both are being developed and acquired using service contracts, NASA's control of aspects of Artemis III mission assurance is not direct. NASA's role and effectiveness in managing risk and safety outcomes for service contracts will be a Panel Focus area for 2025. In addition, there are many essential development-, test-, and validation-related milestones, objectives, and risk assessments related to other system components, not to mention the integrated architecture, necessary to meet the Artemis III baseline launch schedule with a well-understood risk posture.

The ASAP plans to monitor the maturation of Artemis III mission efforts closely, including resolution of the Artemis I heat shield corrective action and its implications for Artemis III. The Panel urges the M2M Program to continue to embrace safety and risk management as the touchstone of its culture. It is important for the Program to maintain a reasonable campaign cadence for Artemis III, but to be vigilant about avoiding unrealistic, unachievable, and overly risky choices. In 2025, as NASA contends with significant development challenges, the Panel will be attentive to the risks associated with adhering to the current schedule, including the potential for operational compromises and alternatives that could reduce risks and enhance mission success.

C. Artemis Campaign Ongoing Concerns

With the establishment of the M2M Program Office in 2023 and its continued maturation, the ASAP believes the current organizational structure, which assigns clear accountability to the M2M Program Manager, is well positioned to address the safety and risk management challenges of the Artemis campaign according to the tenets of a disciplined systems engineering approach. In addition, Artemis leaders have driven the development of a System Architecture across the Artemis mission set that has become a foundational, living

document with an annual review cycle to guide science and technology investments, acquisition requirements, and systems engineering and integration activities and processes.

In the context of this impressive progress, the Panel would like to draw NASA's attention to three specific areas that deserve concerted attention as NASA continues to mature the Moon to Mars effort:

1. Processes to Fortify Architectural Completeness and Risk Management

The ASAP believes expanded application of engineering concepts could further fortify NASA safety risk management and support successful mission execution, and proposes that NASA consider the following:

Design Reference Mission

In conjunction with the System Architecture, NASA would benefit from formalizing a Design Reference Mission (DRM) to define the concept of operations. A DRM is a detailed conceptual framework that outlines how a mission will be conducted, specifying objectives, the systems involved, and operational processes. This engineering tool helps managers evaluate design concepts, trade-offs, and risks while clarifying how various mission components interact. By using a DRM, NASA can optimize the balance between design and operations, identify technology gaps, detect weaknesses in architecture, enhance mission resilience, and refine overall operational concepts. Specifically for Artemis, this would outline how mission objectives can be achieved safely by considering the interaction between system architecture, mission operators, and the space and lunar surface environments. A well-defined DRM would also strengthen resilience by including both nominal (planned, expected) and off-nominal (unexpected) scenarios. These use cases can help uncover potential technical and safety risks early in the engineering process, allowing issues to be addressed at the sub-program level. In the annual report last year, the Panel emphasized the importance of ongoing operator engagement when defining concepts of operations, including for critical elements like vehicle command and control, navigation, and communication—all essential for identifying operational risks early. Ultimately, a DRM provides NASA with a systematic framework for collaboration between operators, engineers, and industry partners, ensuring that risks, gaps, performance limits, and procedures are thoroughly understood and managed.

Mission Objectives

In addition to developing the DRM, NASA should define key mission objectives for each Artemis mission and ensure these objectives are appropriately balanced across the campaign, considering risk and safety. The Panel found discussions with the M2M Program Office promising regarding the scoping of distinct objectives and their assignment to specific Artemis missions. This system engineering method resembles the "all-up" system approach used during the Apollo Program (Figure 3). By distributing major objectives across the Artemis missions and evaluating them deliberately, NASA can balance risks more effectively across the entire campaign. This technique allows the Agency to progressively reduce risk by demonstrating mission objectives and building upon prior successes. Given that Artemis III appears to be overburdened as currently planned, the Panel encourages NASA to adopt this strategy across the full mission set as soon as possible.

Lessons From Apollo: Buildup of Mission Capability

From NASA-SP-287, "What Made Apollo A Success?" (Undated circa 1971)

- "The flight-test program shown in figure 1-7 was then evolved through an **iterative and flexible process** that was changed as time went on to take the **best advantage of knowledge** about mission operations and hardware availability at any given time."
- "The basic principle in planning these flights was to gain the **maximum new experience** (toward the goal of a lunar landing) on each flight **without stretching either the equipment or the people** beyond their ability to absorb the next step."
- "**Too small a step** would have involved the risk that is always inherent in manned flight, without any significant gain – **without any real progress** toward the lunar landing."
- "**Too large a step**, on the other hand, might have stretched the system beyond the capability and to the point where **risks would have become excessive** because the new requirements in flight operations were more than people could learn and practice and perfect in available time."

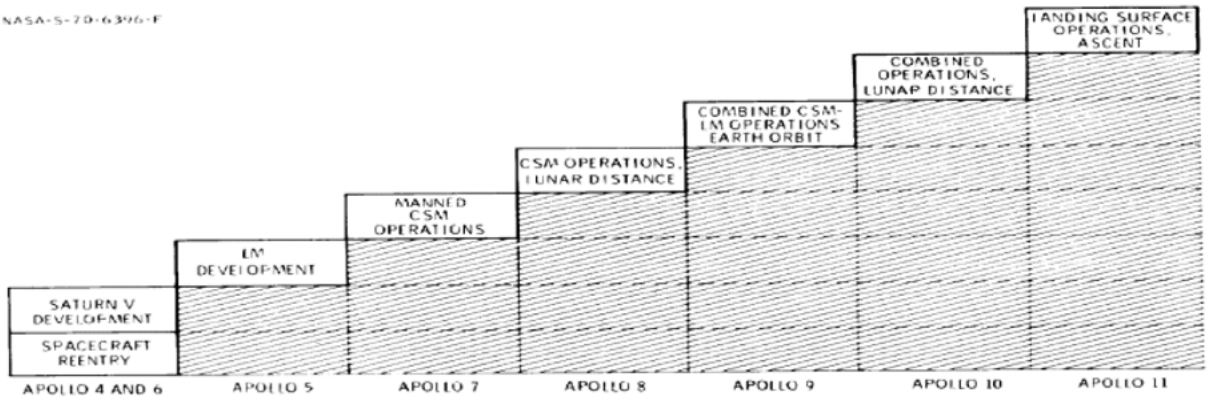

Figure 1-7. - Buildup of Apollo mission capability.

Figure 3. Lessons from Apollo mission objective build-up.

2. Risk Management: NASA as the Prime Integrator

Since the M2M Program office was established in 2023, the Program Manager has impressed ASAP with sound judgment and proactive leadership of the M2M team. After organizing rapidly, the program office began to address the key functions of a prime integrator, as described in the 2023 Annual Report (Figure 4). As noted, NASA's approach to Artemis varies from that previously employed for major programs such as the Space Shuttle and Apollo, which relied on a contractor as the prime integrator. Specifically, NASA's acquisition strategy and contracting methodology both position the Agency itself as the prime integrator for the M2M program and Artemis campaign. This is a significant role for NASA that will require flawless execution if this campaign is to succeed.

Figure 4. Critical activities a prime integrator performs across the integrated program.

Over the last year, the ASAP conducted several fact-finding sessions with the M2M participants in the Artemis campaign. To be able to manage the integrating role that has historically been accomplished by a prime contractor, NASA must maintain a strong and disciplined program management and systems engineering workforce able to lead key integrating functions. This requires a strategic approach to human capital to sustain a pipeline of engineering talent. NASA will also need to craft an approach to integration effective in a new era of major service contracts and significant contributions by international partners.

In the coming year, the Panel will be interested to learn in depth how NASA plans to manage and integrate risks across numerous partners with varied roles and responsibilities. In particular, the Panel seeks to understand how NASA will conduct risk assessments across the integrated program—not only identifying, understanding, mitigating, and eliminating individual subprogram risks, but also aggregating risks and dispositioning them at the Artemis system level. So far, the Panel has seen substantial progress and maturation of the risk process, a highlight of NASA's success over the last year. The M2M Program Manager has made risk management a cornerstone of his program culture, and his express stance is not to "admire the risks but rather take action against them, to eliminate or mitigate them." The ASAP commends the Program Office's efforts and looks to gain continued insight as their methodology and approach mature.

3. Risk Management: Artemis Integrated Acquisition Strategy

Acquisition strategy directly impacts integrated risk management. In recent years, NASA has improved its acquisition strategy development approach, linking decision-making to architecture needs and top-level requirements, understanding interface requirements, and prompting more thoughtful discussion of contract goals much earlier in the acquisition process. New acquisition strategy development processes initiated over the last two years have enabled a richer and a more informed dialogue that should yield more robust arrangements.

That said, in the past decade, many Artemis service contracts were awarded without benefit of a high-level defined architecture and thus somewhat in isolation from one another. As a result, there are programmatic, technical, integration, and mission-risk disconnects across them. With the establishment of the M2M Program Office as a single accountable authority for the execution of the Artemis Campaign, the burden of integrating these disparate contracts now falls to the M2M Program Manager, especially in the context of NASA as the prime integrator. As the ASAP has previously expressed, alignment, coordination, and engineering integration of individual delivery contracts will be critical to the success of the program.

It is not yet clear to the ASAP how NASA, in its service contracts, clearly defines risk accountability and ensures this is clearly understood by all parties well before a contract is signed. NASA must explicitly understand and articulate where the risk allocation and acceptance "line is drawn" for each contract—that is, what the contractor's risk is, what the government's risk is, and what is shared risk. Likewise, the contract type, clauses, and incentives must be clearly delineated before contract award to ensure all parties understand roles and responsibilities. Without clarity, unknown and sometimes unbounded risk can emerge in execution and create confusion that is difficult to resolve.

Given the implications of contractual relationships, roles, and responsibilities for technical execution, risk accountability, and safety, the ASAP plans to focus closely on this in 2025. The Panel seeks better insight into how NASA develops its acquisition strategies, decides on contracting approaches, and determines risk balance between the government and contractor within the Artemis campaign, but also broadly across the Agency. The Panel is also interested in understanding NASA's rationale for broad use of "service" contracts and reliance on Firm Fixed Price approaches for acquisitions, particularly when applied to developmental items that are notably necessary for mission assurance. ASAP plans to focus on contract management in 2025 and looks forward to furthering engagement with NASA acquisition leaders.

V. The Future of US Presence in Low-Earth Orbit

A. Commercial Crew Program

2024 was a monumental year for the CCP with two SpaceX crew rotation missions and the Boeing Crewed Flight Test (CFT). From a risk and safety perspective, NASA's most noteworthy event of the year was the CFT of the Boeing Starliner spacecraft. This milestone was notable not only as the first crewed flight of a new spacecraft for NASA astronauts but also for the in-flight contingencies that tested the Agency's risk management practices to their limits. The CFT presented one of the most complex and challenging crew safety decisions NASA has faced in years. Despite these complexities and uncertainties, the Panel concludes that NASA took a thoughtful and effective approach to assess and manage risks, implementing a cogent decision-making process rooted in a strong safety culture. NASA's leadership demonstrated courage and fortitude, leveraging the prowess of a dedicated technical workforce to successfully navigate emergent challenges.

Boeing Starliner Crewed Flight Test: A Case of Safety Culture

In June 2024, the Boeing Starliner spacecraft embarked on its first crewed mission, carrying astronauts Barry Wilmore and Sunita Williams. The mission, launched from Cape Canaveral, was set for a minimum eight-day journey to the International Space Station (ISS) to meet all the preflight defined flight-test objectives. However, during the approach to dock with the ISS, the Starliner encountered a series of technical failures that would test NASA's risk management protocols to the extreme. The spacecraft's Service Module Reaction Control System (RCS) used for translation and maneuvers near the ISS and for attitude control experienced multiple failures due to helium manifold leaks, and several RCS thrusters that overheated, making them temporarily unavailable for usage by the flight control system.

Faced with this situation and after assessing the best options for crew safety, the crew flew manually within 250 meters of the ISS to allow the recovery of the RCS thrusters via a preplanned hot fire technique. After the recovery of four of the five thrusters, Starliner successfully docked with the ISS. With the crew safely aboard the ISS, NASA and Boeing immediately began investigating the cause of the failures. Over the next several weeks, ground teams conducted thorough testing and analysis to understand the behavior of the spacecraft's systems and determine if the risk to the crew could be sufficiently mitigated.

After approximately two months of evaluation, it became clear that the risk associated with the Service Module RCS thrusters for the undock-through-deorbit phase remained uncomfortably high due to inability to quantify the risk of subsequent thruster failures.

Unlike previous space missions that offered no options for crew return beyond the vehicle that had launched them, the Starliner mission had a critical advantage: the availability of the SpaceX Dragon capsule. With the ISS program able to accommodate additional crew members for an unplanned two to three months, NASA was able to consider using Dragon for the CFT crew's return.

Early in the process, the ASAP wondered whether NASA would fully assess the Dragon option, given the significant risk posed by the thruster failures. However, NASA did expand its risk analysis to include this possibility. Notably, the core objectives of the CFT mission—those requiring crew presence on Starliner—had already been completed upon docking. Therefore, mission success no longer depended on the crew returning on the Starliner.

The NASA team took appropriate time to assess the situation, weigh all options, and identify the safest option for crew return. SpaceX, CCP, and the ISS program did an extraordinary job positioning NASA for successful planning and resolution of the Starliner and crew return. Ultimately, NASA made the decision to keep the astronauts aboard the ISS for an extended stay, with a planned return on the SpaceX Crew-9 Dragon. The ISS program coordinated to adjust crew rotations accordingly. This decision ultimately ensured that the crew would return safely while minimizing the risk associated with the Starliner's technical issues.

Overall, Starliner performed well across all major systems in the undock, deorbit, and landing sequences; however, an additional mono propellant thruster failure was discovered in the Crew Module—distinct from the failures in the Service Module experienced during orbit. Had the crew been aboard, this would have significantly increased the risk during reentry, confirming the wisdom of the decision.

Despite the intense pressure and weeks of long, exhausting hours in a highly stressful environment, NASA's commitment to safety stood out as a driving force throughout the entire process. NASA's Technical Authority experts had an appropriate voice in the process, and a broad array of stakeholders were integrally involved in decision-making, ensuring that all relevant perspectives were thoroughly considered. NASA's approach was grounded in a rigorous safety-first philosophy: the Agency presumed risk, demanding proof that the mission was safe rather than assuming safety and forcing dissenters to prove otherwise.

The senior leadership team at NASA, including the Administrator, Deputy Administrator, and Associate Administrator, maintained close engagement in the decision-making process, ensuring the Agency's culture of safety remained at the forefront and pervaded the process. The ASAP's engagement as close observers, including in Flight Readiness Review (FRR) meetings, enhanced the Panel's ability to assess the Agency's safety

processes and provide value to the Agency during separate insight meetings by asking hard questions and flagging potential "blind spots," and is a recommended best practice for similar situations in the future.

Ultimately, the resolution of the Starliner CFT anomaly demonstrated that, even in the face of unexpected and complex challenges, NASA's commitment to safety is unshaken. The lessons learned from the past tragedies of Challenger and Columbia continue to influence the Agency's safety culture today, ensuring that risk management and crew safety are paramount in every decision.

There is much to learn from the Starliner CFT anomaly. A leadership-directed post-event investigative team is charged with capturing and documenting lessons, and the ASAP will be interested to review these observations and recommendations. Ahead of that, it is already evident this case illustrates the pressing need for clear roles and responsibilities for service providers with respect to risk. As the process to resolve the anomaly unfolded, especially around determining crew safety, NASA and Boeing confronted the need to clarify who had the appropriate authority and responsibility for key decisions involving risk and safety. As one example, the Panel observed ambiguity in the interrelationship between an initial Boeing-directed Mission Management Team (MMT) meeting, where data were assessed, and a subsequent NASA-led Commercial Crew Program Control Board that sought further analysis. Similarly, the ASAP was unclear about how the decision was made to waive the failure tolerance level requirement for Crew Module RCS thrusters apparently without the appropriate flight or qualification data to justify this decision.

These examples illustrate the Panel's concern that, absent role clarity, risk management choices could unintentionally devolve to contractors, whose interests may not fully align with NASA's. The ASAP had queried key NASA leaders about this possibility ahead of the CFT mission and received assurance that risk management authorities and responsibilities were well understood. Under the scrutiny of post-event review, however, the NASA investigative team is likely to discover opportunities to strengthen risk management roles and responsibilities. Regardless, the Panel urges NASA to establish clear contractual and programmatic direction regarding roles and responsibilities within the CCP, including the structure and use of MMTs for anomaly resolution, particularly when addressing significant in-flight anomalies that could affect crew safety.

Meanwhile, the ASAP will continue to monitor resolution of the Starliner Reaction Control System anomalies and seek information about NASA's and Boeing's plans for certification of the vehicle. While the thruster issues have received considerable attention, the Panel has previously noted other Starliner issues that require resolution prior to certification, such as a battery redesign plan and ongoing work to strengthen the landing airbag backing panel to increase operational flexibility. And, beyond these technical matters, schedule and budget pose substantial challenges to Starliner certification.

NASA's intent has been to have two CCP providers supporting human transportation to and from the ISS for redundancy and greater resilience, but until the Starliner certification plan is well understood, it remains unclear as to whether a second provider will be available prior to the end of the ISS's operational life. As noted in the 2023 report, while NASA could potentially realize a benefit from having a reliable second provider, NASA should regularly review its risk-benefit analysis to ensure the overall risks of its plans remain acceptable.

In 2023, the ASAP also remarked on challenges SpaceX faces given its very high operational pace. The Panel advised NASA to track issues and commensurate risks fleet-wide. SpaceX's operations tempo remains a concern with the increased pace of Falcon 9 operations, the addition of west coast–based Dragon crew and cargo spacecraft recovery, the award of the United States Deorbit Vehicle (USDV) contract to SpaceX, and the ongoing large-scale Starship development program. The Agency made considerable progress assessing the associated Falcon 9 and Dragon risks from all flights executed in 2024. In 2024, SpaceX successfully launched its first crewed Dragon mission from Space Launch Complex 40, a new launch site activated to help mitigate future potential schedule risks for crew and cargo launches. SpaceX also addressed oxidizer valve corrosion in the propulsion system on reused Dragon capsules. That said, several new anomalies emerged in 2024 that require close scrutiny:

- Crew-8 main parachute opening delay and drogue debris strikes. Additionally, skip stitching was observed on five flights.
- Starlink G8-6 Hard Landing Investigation.
- Starlink G9-3 S2 Merlin Vacuum Engine (MVacD) Anomaly.
- Crew-9 S2 MVacD De-Orbit Mishap.

NASA is appropriately sensitive to the importance of tracking anomalies and the potential detrimental impact of an accumulation of numerous small issues. Likewise, SpaceX has been very thorough and open with NASA on all anomalies that could potentially impact future NASA operations, whether they occurred on NASA or other customer missions, and is to be commended for their openness with NASA and willingness to address each situation. The ASAP cautions NASA and SpaceX to maintain their intense focus on safe Crew Dragon operations and be alert both to complacency and schedule pressure. NASA and SpaceX must guard against allowing the fast-paced operating environment to interfere with sound judgment, deliberate analysis, and careful implementation of corrective actions.

B. International Space Station

The ISS program continued its keen stewardship of what is a very complex and dynamic program. In 2024, typical of their long legacy of unerring management, they seamlessly met anomalous challenges that could otherwise have resulted in serious setbacks to daily operations. Their ability to adeptly accommodate the Starliner CFT crew for an unexpected and protracted stay on board the ISS—thanks in part to their foresight to stage SpaceX Dragon launch and entry spacesuits for a variety of ISS challenges and failure scenarios—is a telling example of their thorough strategic approach. Extending the crew on the ISS was, of course, a contingency plan that eventually became NASA's best option to protect crew safety and highlights the benefit of operational flexibility to safety and risk management.

NASA's ability to sustain strong operations with risks properly managed has always been grounded in its agility to balance and select options considering technical issues, many of which have direct implications for crew safety and rely on the ISS capability. In an ever more stringent budget environment, it is increasingly difficult for NASA to ensure the risk of ISS operations remains manageable for day-to-day operations with enough contingency margin. To date, the ISS has been adequately resourced to operate safely, including being prepared to handle unforeseen situations like accommodating the CFT crew. With the advent of the M2M program, Commercial LEO Destinations, and other programs with significant demands competing for resources, the ISS operating budget may well be reduced to a level that will negatively impact operational flexibility.

Even as the ISS budget decreases, hazards are accumulating as the ISS ages, increasing risk and limiting operational capability. Most urgently, the increase in leaks over the years from cracks in the Russian Service Module vestibule (the PrK) hull is a significant safety concern that will likely worsen. NASA and the Russian teams are working to understand the PrK cracking, but they do not share a common understanding of the root cause nor of the consequences of leaking—Russia believes the cracking is driven by fatigue and NASA believes the root cause is more complex. NASA sees resolution of the leaks as an urgent priority, has characterized the cracks and leaks as the highest possible risks, and tasked an independent review panel to help assess this problem. In the face of these unknowns, the Panel commends NASA for taking operational precautions to protect the crew. (Specifically, when the hatch to the PrK is occasionally open for logistical reasons, NASA directs the US crews to close a hatch between the US and Russian segments to minimize risk to crewmembers in the US Orbital Segment.)

Another persistent and critical risk for the ISS is the obsolescence of the Extravehicular Mobility Unit (EMU), a concern the Panel has previously discussed and about which the concern is growing. In 2019, the ASAP recommended that NASA begin an immediate transition to a next-generation Extra-Vehicular Activity (EVA) suit system.

2019-02-01 Recommendation: NASA should begin an immediate transition to a new-generation Extra-Vehicular Activity (EVA) suit system EMU, before the risk to EVA becomes unmanageable.

The ISS EMUs have been in use since the early Space Shuttle flights and are now well beyond their design life. Last year, NASA had a contract arrangement to develop improvements for the ISS suit to sustain operations through ISS decommissioning. Unfortunately, the follow-on ISS spacesuit program encountered a setback when the contractor withdrew from the contract, leaving NASA without development to deliver a next-generation ISS EMU.

The ISS provides a capability as a critical test bed where NASA and industry partners can test and develop their space-based capabilities to demonstrate and validate mission assurance and safety. NASA's Artemis program is using the ISS to test the Universal Waste Management System (UWMS) that will serve as the toilet for the Orion capsule and as a backup to the aging US ISS toilet. Of note, the UWMS has struggled to perform reliably since its 2021 technology demonstration aboard the ISS, and the technical, budget, and schedule challenges associated with completing the development of the UWMS are concerning. This is but one example of hardware that must be adequately tested in a space environment to support appropriate safety and health of the crews assigned to the Artemis campaign.

Beyond serving as a risk-mitigation test bed for Artemis space hardware, the ISS is also critical to human research necessary to enable the long-duration space flight on which the M2M Program rests. ISS program budget constraints have reduced the frequency of resupply missions, could result in fewer crew rotation missions, and could reduce how much human science can be conducted. This work is not optional, but absolutely critical for safe human space flight. Thus, the complex space platform that is the ISS must be resourced so it can operate safely until alternatives can be made available and the ISS is decommissioned.

To that point, the ISS's service life has already been extended several times and additional extensions would be expensive and risky. Most ISS partners have agreed to decommission the ISS by 2030, before the overall risks become unmanageable. So far, Russia has only agreed to extend ISS service to 2028. For more than a decade, ASAP has noted the ISS deorbit plan as a major concern, both for end of life and, if warranted, an unplanned emergency deorbit. In 2022, the Panel made a recommendation on ISS deorbit capability:

2022-05-01 Recommendation: NASA should define an executable and appropriately budgeted deorbit plan that includes implementation on a timeline to deliver a controlled re-entry capability to the ISS as soon as practicable—to be in place for the need of a controlled deorbit in event of an emergency as well as in place before the retirement of the ISS—to ensure that the station is able to be deorbited safely.

As of June 2024, NASA funded a contract with SpaceX to provide a USDV to support an ISS End of Life (EOL) timeline of 2030. The SpaceX USDV design is a modified version of the cargo Dragon vehicle, and the proposed development timeline appears reasonable to meet the required launch date of mid-2029. NASA has also made good progress addressing an emergency ISS deorbit capability prior to USDV arrival and has an ISS Contingency Deorbit Protocol in place outlining a high-level strategy. Additionally, the ISS program will maximize ISS propellant deliveries to ensure propellant availability for contingency orbit reserve. Given the release of the USDV contract and that NASA has plans to accommodate controlled ISS deorbit for emergency scenarios, the Panel believes NASA's response to the recommendation will significantly lower the risk to the public for both planned and emergency ISS deorbit scenarios and intends to close this recommendation.

The Panel has grave concerns, however, that if the necessary funds for both the USDV and the supporting launch infrastructure (over $1B in total) comes solely from the existing ISS budget, this will unduly strain NASA's ability to safely perform normal and contingency ISS on-orbit operations, especially as the ISS approaches EOL. Although NASA is searching for additional funding to cover the costs of the USDV, it is unclear how programs, operations, and safety will be impacted if no additional funding is granted. In the Panel's view, the ISS program must be allocated the appropriate budget to both manage the necessary preparations for safe ISS disposal and to safely manage a complex space laboratory platform with increasing failure rates and aging hardware until it is formally decommissioned.

C. Transition to Commercial Low-Earth Orbit Destinations

The Panel greatly appreciates the efforts of the ISS Program to make as much use as possible of the space station until its end of life. It is not clear, though, that the remaining ISS life is sufficient to meet all critical test and research objectives necessary to support development and reduce risk for the Artemis campaign and beyond. Accordingly, the Panel made the following recommendation in 2023:

2023-04-01 Recommendation: NASA should develop a comprehensive understanding of the resources and timelines of the ISS-to-CLD transition plan to a much higher level of fidelity, to provide confidence that the Nation will be able to sustain a continuous human presence in LEO. The plan should be grounded in explicit, defensible assumptions and should include quantifiable metrics and progress deadlines for ensuring that the market for commercial LEO activities exists and is sufficient to support the development, production, and operation of one or more commercial platforms to replace the ISS.

The Panel applauds NASA's plan to shift critical research and technology development from the ISS to Commercial Low Earth Orbit Destinations (CLDs). In 2024, NASA briefed the Panel several times on the status of the various CLD programs in development and the extent to which they will be able to meet NASA's research requirements and health and safety standards.

Importantly, NASA's ability to sustain a human presence in LEO depends on a successful transition strategy. The Panel's view is that NASA's current strategy appears aspirational, as it lacks a clearly defined and executable path to transition to a CLD before or immediately after the ISS EOL. As noted in 2023, NASA needs to fully articulate detailed objectives for sustained human presence in LEO; outline a practicable transition of objectives to alternative LEO platforms; identify NASA's roles, responsibilities, and authorities for operations on CLD platforms it neither owns nor maintains; and develop a feasible supporting budget. As described a year ago, much study of CLD options has been accomplished and a substantial transition effort is underway, somewhat akin to how objectives are developed for the Artemis campaign (see Figure 5). A viable transition strategy remains forward work, however.

Figure 5. LEO goals (as of October 2024).

The Panel also noted previously that the transition to a commercially owned and operated destination raises many fundamental strategic, technical, and operational questions, several of which are not answerable by NASA alone. For example, NASA must be convinced a potential provider has the technical and financial wherewithal to manufacture a CLD and operate it successfully long-term. They must be able to construct it, acquire and fly the number of missions needed to assemble it in space, and create a livable science-ready interior bay. They must also have realistic access to a non-NASA client base that will contribute significantly to covering the cost of operations and eventually provide a viable commercial return.

For emphasis, the ASAP repeats here questions previously raised, the answers to which are necessary to ensure NASA can successfully transition LEO research and technology efforts from the ISS to a CLD:

- How will NASA determine which CLD options are viable for ISS transition, both technically and financially?
- How much is the US Government willing to invest in the CLD market to ensure an orderly LEO transition?
- Will there be a consistent US Government position on NASA's role in LEO operations?
- Without US Government investment, is there a viable CLD market within NASA's necessary timelines for ISS retirement?
- What will be the future regulatory paradigm for CLDs, and will Congress designate a US regulator?
- With numerous elements as part of the broader system of systems, many of which will be industry-owned and -managed, who has the authority and responsibility to support safe and effective operations, and how will NASA have a role in that authority?
- What are the acquisition or investment approaches (near-term and long-term) that will allow the Agency to understand the risks to NASA personnel and resources, and how will integrated risks be addressed?
- As a risk-reducing platform for the M2M program, to what extent will risks for the Artemis campaign be retired by the time the ISS reaches its planned EOL in 2030?
- How will new and emerging risks be addressed in a timely and cost-effective manner without the ISS?
- What role will CLDs play in astronaut training for the M2M program, and how will CLD crew training be accomplished in a way that translates to Artemis risk reduction?
- How will NASA be assured that CLDs can support the infrastructure to conduct mission-essential research?
- How does NASA envision using the CLD operations to support and sustain workforce expertise required for overall human space flight experience?

In the past two years, NASA has funded initial design studies for three potential CLD groups, and there are others who have expressed an interest. Because NASA expects to contract for services with a CLD provider, the design, build, deployment, and operational costs will be the responsibility of the provider. It will be important for NASA to clearly define human certification requirements and provide them in the contract award. Further, the Agency must carefully consider what additional risks arise because of very limited insight, involvement, and participation in the development and operation of a CLD and determine how to mitigate those risks, especially as NASA's own knowledge base and direct experience degrade over time post ISS EOL. The Panel will continue to monitor NASA's progress against these questions in 2025.

VI. Health and Medical Risks in Human Space Exploration

As highlighted in ASAP's 2023 Annual Report, health and medical risks in human space flight are integral to the overall mission risk and safety profile. These risks arise from exposure to factors such as toxic substances, microgravity, space radiation, and isolation. Medical risks, including the potential for crewmember illness or injury, are mitigated through medical selection processes, on-board treatment capabilities, and space medicine practices. NASA sets acceptable exposure levels through nationally vetted health standards, which are managed by the Health and Medical Technical Authority. Probabilistic Risk Assessment is used to assess and manage medical risks and to guide resource allocation.

For missions beyond LEO, NASA faces additional challenges, including limited ability to evacuate astronauts and constraints on medical systems. While lunar missions are shorter in duration, they present unique challenges, such as the inability to quickly return astronauts to Earth. For Mars missions, understanding human resilience in space is crucial. In 2024, the Panel engaged NASA's health and medical authorities to better understand how these risks contribute to the overall mission risk and safety profile. This included discussions with the Office of the Chief Health and Medical Officer (OCHMO) and the Human Research Program (HRP), which collaborate to identify and mitigate health risks for exploration missions. OCHMO is responsible and sets standards for the health of the NASA workforce, while HRP conducts applied research to address space flight–related risks such as radiation, isolation, microgravity, and the hostile space environment.

Engaging with the Panel, OCHMO and HRP staff addressed questions raised in the previous annual report by applying a framework of primary, secondary, and tertiary care for managing astronaut health. Primary care focuses on health standards and crew selection. Secondary care includes countermeasures, such as those for radiation and behavioral health, which require ongoing LEO access for validation. Tertiary care involves medical tools like the IMPACT (Informed Mission Planning via Analysis of Complex Tradespaces) system, which uses probabilistic risk assessments to guide mission planning and medical interventions.

The Panel learned why HRP's research is so essential for understanding long-duration flight risks, and how insights from the ISS directly inform the health risks anticipated for Mars missions. HRP is advancing understanding of biology in lunar, Mars, and deep space environments, which will lead to improved crew health through the gradual development of medical technologies. In preparation for Mars missions, HRP has developed strategies to address critical gaps, such as food systems, exercise countermeasures, and the physiological effects of long-duration missions. In addition, new risks, such as jugular venous thrombosis, continue to emerge as missions increase in duration and prompt focused investigation.

The Panel is encouraged by the robust and comprehensive approach taken by HRP, which provides sound science and will help mitigate the unique risks of long-duration space flight. The Panel also recognizes the critical need for continued LEO research as a key risk mitigator. To state it plainly, to mitigate risk and uncertainty and to bolster the safety of astronauts destined for Mars, the continued accomplishment of human research in LEO is a safety requirement, as Figure 6 illustrates.

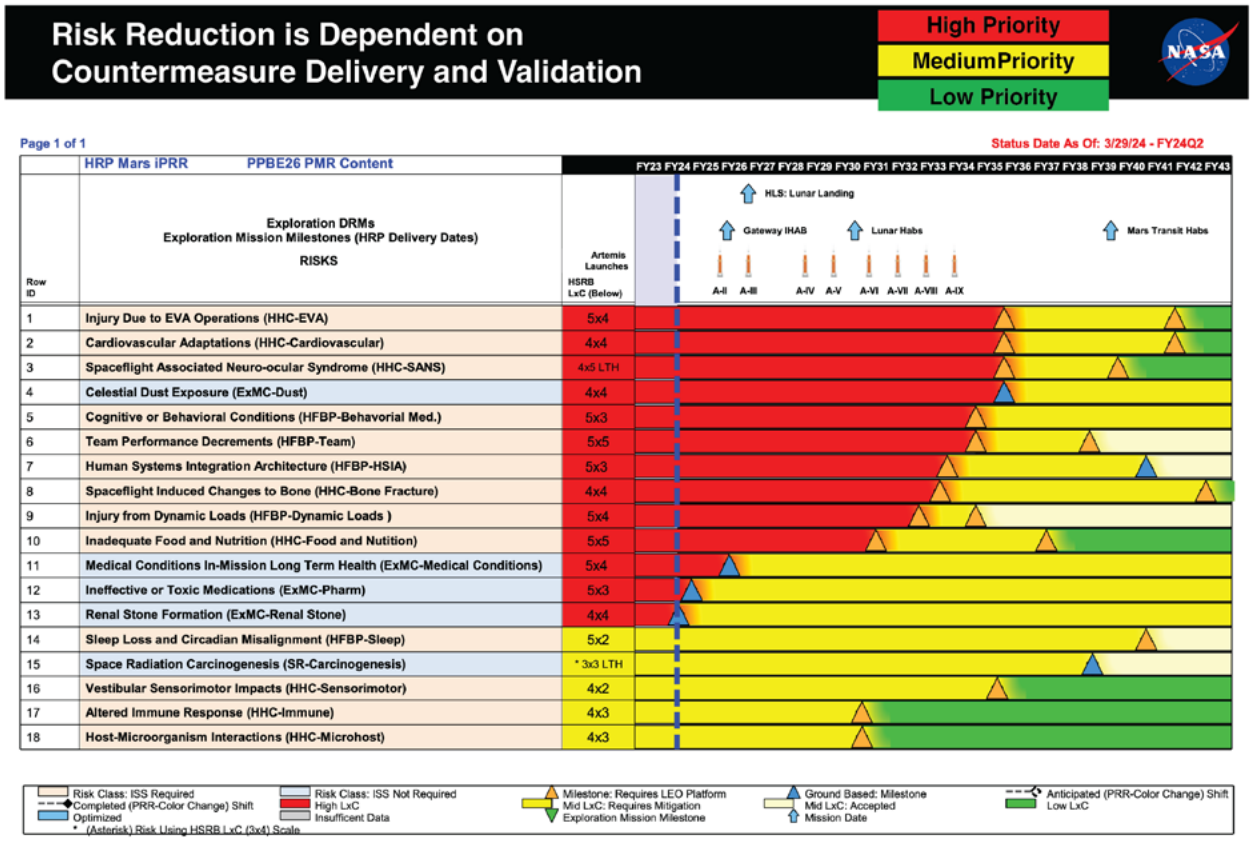

Figure 6. Human Research Program risk reduction.

The Panel remains concerned about the loss of ISS research once it is decommissioned. The applied research conducted through ISS crew increments (typically six months long) is crucial for understanding and mitigating the risks associated with long-duration exploration missions. ASAP urges prioritizing continued access to LEO for vital health research. Without this research, managing long-term exploration risks could be unfeasible. The Panel calls for uninterrupted human research to ensure astronaut health and mission success for future Mars exploration.

VII. Focus for Congress

The scope of issues the ASAP reviewed in 2024 underscore the complex environment of geopolitical and fiscal realities in which NASA operates, facing challenges unlike those of its earlier years. The Panel cannot emphasize strongly enough that ongoing budget constraints and uncertainty have a direct impact on NASA's ability to manage risk across its human space flight programs, especially concerning crew safety.

NASA's current mission is its most ambitious to date, but it no longer enjoys the same advantages it once did. Historically, NASA functioned independently, but today it increasingly relies on commercial and international partners. Moreover, NASA must operate within the confines of past executive and legislative decisions, which limit organizational flexibility. Although these legacy directives may have been suitable in the past, they constrain NASA's ability to fulfill the high expectations placed on the Agency. Crucially, NASA no longer has access to the level of fiscal resources it enjoyed during the Apollo era, despite having broader and more ambitious mission requirements. In the 1960s, NASA was supported by substantial financial allocations—possible in an environment where overall discretionary expenses were almost forty percent of the national budget. However, both the discretionary budget and NASA's proportion of it have significantly shrunk over the past 50 years. Despite these budgetary constraints, NASA is still tasked with achieving national priorities safely and effectively.

The current budget environment poses significant challenges for mission planning and risk management. NASA leadership must make critical decisions about program content and schedules to align with fiscal realities. Attempting to fulfill all mission objectives on expected timelines with insufficient resources will introduce unacceptable and unmanageable risks. The Agency will need to rely on its developed strategic vision, objectives, and architecture to establish well-defined priorities and ground its endeavors in reality and make risk-benefit trade-offs accordingly.

It is vital that NASA be transparent with stakeholders and its workforce about these fiscal realities and the choices they necessitate. Stakeholders must have realistic expectations about schedules, and NASA cannot yield to external pressures to exceed these rational anticipations. The workforce must be confident that NASA leadership's expectations are reasonable and achievable. NASA's talented workforce has traditionally shown unwavering dedication to challenging goals, but if employees believe they are embarked on a risky journey that is not realistically achievable due to resource constraints, morale will suffer, and a robust safety culture cannot be sustained.

An even greater challenge lies in the persistent budget uncertainty stemming from Congress's failure to provide timely and definitive appropriations. This ambiguity significantly hampers NASA's ability to plan for and execute highly technical missions. Budget uncertainty can escalate risks during development and create operational risks later on. It also diverts attention from critical work, introduces inefficiencies, and delays important decisions that directly impact safety and mission success. Given the likelihood that Congress will not provide timely budget clarity, NASA must be candid about the consequences of operating within this uncertainty. Congress and other stakeholders must also understand the negative impacts this uncertainty has on NASA's ability to execute missions safely and effectively.

These challenges are exacerbated by the consequential relationship between safety and robust acquisition practices, a recurring concern for the Panel. As NASA increasingly engages the commercial sector for its missions, the complexity and diversity of its acquisition strategies grows. The Panel believes that strong acquisition experience is essential at all levels of NASA leadership. While NASA has made commendable strides in strengthening program management and acquisition skills within its workforce, the Panel still advocates for the creation of a Chief Acquisition Officer (CAO) role akin to other government agencies that manage complex acquisitions. This position should be filled by an individual with substantial acquisition experience to ensure NASA's continued success in managing complex contracts and partnerships. Therefore, the Panel resolutely urges Congress to require acquisition experience for the Senate-confirmed appointee to the CAO role at NASA.

VIII. Conclusions and Looking Ahead to 2025

In 2024, NASA faced numerous challenges and achieved significant successes. The M2M program office continues to evolve alongside the development of Artemis' integrated risk and safety management processes. The NASA 2040 initiative is making impressive progress, and the Panel looks forward to the implementation of necessary changes across the Agency to achieve NASA's goals. Despite budget constraints, the ISS program management team has demonstrated remarkable agility and mission success while maintaining a culture that prioritizes crew safety. The CCP tested NASA's ability to manage risk and uncertainty under immense internal and external pressures. Ultimately, it highlighted NASA's strong cultural foundation for addressing the critical safety question: "Do we have a comprehensive understanding of the risks to the crew on which to base sound decisions?"

As the Nation's technical leader in space operations and environments, NASA continues to learn valuable lessons alongside commercial and non-commercial industries about which contractual relationships are most effective, particularly in an era of increasing interest in commercial revenue-generating opportunities. The ASAP has observed significant variation in contract types and their impacts across NASA's programs in 2024, particularly as NASA supports commercial industries joining traditional sectors to build the space economy. NASA's contract options—ranging from Cost-Plus contracts (with a contractor fee) to Fixed-Price contracts, each with different terms—play a crucial role in fostering innovation, improving efficiency, managing risks, and ensuring operational safety. ASAP has also noted an increasing use of "service" contracts, where NASA procures services to meet mission requirements rather than overseeing a contractor's development and production processes directly.

The safety implications of these contract choices depend on who—NASA or the contractor—assumes responsibility for specific risks during program execution. Looking ahead to 2025, how NASA manages risk and mission assurance through its choice of acquisition strategies and contract structures will be a key area of focus for ASAP. The Panel sees an opportunity for NASA to apply lessons learned from various contracting mechanisms to improve both program performance and safety. This focus will extend to several initiatives, including current operations and future deorbit planning for the ISS, the transition to CLD, and the Artemis and Commercial Crew programs.

Beyond acquisition and contracting strategies, the Panel will maintain its focus on NASA's and Congress's progress toward meeting the current open recommendations. In addition, the Panel will delve further into the state of integrated risk of the early Artemis missions, particularly Artemis II and III. The budget environment, particularly with respect to the ISS Program, has the Panel greatly concerned, and the Panel intends to explore the safety implications of budget constraints. The development of Commercial LEO destinations and the ISS transition strategy have the ASAP's attention, as NASA's ability to safely send humans on long-duration exploration missions directly depends on continuing presence in LEO to accomplish human research and other risk mitigation. Other topics will include a safety review of the X-59 and NASA's latest approaches to enterprise protection. Finally, the Panel will assess the results of the annual Safety Culture survey and continue to monitor integrated risk management through technical, organizational, and cultural lenses.

NASA's work is exceptionally complex and challenging, carried out in a demanding environment that requires constant vigilance to ensure safety and effectiveness. The Panel commends NASA for its impressive efforts in 2024 to strategically enhance the Agency's risk management posture. The ASAP thanks NASA's leaders and workforce for their passionate dedication to space exploration and their unwavering commitment to the safe pursuit of the Nation's lofty aims to the great benefit of the future of humankind.

Appendix A

Summary and Status of Aerospace Safety Advisory Panel Open Recommendations

Each previous year's recommendation has an associated action color. **RED** highlights what ASAP considers to be a long-standing concern or an issue that has not yet been adequately addressed, or for which there is no identified resolution. **YELLOW** highlights an important ASAP concern that the Panel is 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.

2023-04-01: Establishment of a Comprehensive International Space Station (ISS) to Commercial Lower Earth Orbit (LEO) Destination (CLD) Transition Plan

Finding: Perhaps the most far-reaching concern about planning for the end of the ISS Program is the need for timely and assured transition of the capability for living and working in LEO to the CLD. NASA's current plan for transitioning from ISS to one or more commercial destinations features a high-level framework and a timeline that is very tight. The Panel, being watchful of this extremely tight schedule, remains concerned that there is not a clear, robust business case for commercial LEO, nor clear evidence of the financial viability of the commercial destination for ISS and free-flyer destinations, creating programmatic and safety risk with the entire plan for NASA LEO. If these new commercial platforms are not complete and operational before the ISS is deorbited, the United States (US) will face the loss of its ability to perform vital scientific research in weightless conditions, research essential for minimizing safety risks posed by future space exploration activities and specifically the Artemis Program.

Recommendation: NASA should develop a comprehensive understanding of the resources and timelines of the ISS-to-CLD transition plan to a much higher level of fidelity, to provide confidence that the Nation will be able to sustain a continuous human presence in LEO. The plan should be grounded in explicit, defensible assumptions and should include quantifiable metrics and progress deadlines for ensuring that the market for commercial LEO activities exists and is sufficient to support the development, production, and operation of one or more commercial platforms to replace the ISS.

Rationale: Managing and understanding integrated risk across the complex transition from ISS to CLD is challenging and requires a clear rationale; a strong business case; and a viable, executable plan. In the 2022 Annual Report, the ASAP noted that the transition to a commercially owned and operated destination raises many fundamental strategic, technical, and operational questions. Specifically, NASA should ask and answer the following questions: What are the US Government's desired goals and objectives in LEO? Are NASA's goals and objectives dependent on the development of a non-government-driven LEO market? If so, how big is this market, how much is the US willing to invest to get it, and who is responsible for developing that market? Who is responsible for defining and certifying that commercially owned and operated orbiting facilities are safe? What is the acquisition or investment approach that will allow the Agency to understand

the risk they are accepting? How will the Agency address shared risks between the government and industry? And what will be the role of NASA's workforce in LEO operations in the future and what skill sets are needed?

As stated in 2022, "the Panel believes that NASA's activities in LEO can benefit from a similar approach in strategically outlining architecture, requirements, systems engineering and integration, and integrated schedule and program management as is being applied to the Artemis campaign."

If this program fails, NASA would be facing two very undesirable options: either extending ISS further or abandoning LEO. Abandoning LEO has significant implications for NASA's ability to manage risk in the Moon to Mars (M2M) Program, which is perhaps the most compelling reason a viable CLD is vital. Specifically, the LEO environment allows the M2M Program to train crew, test equipment, investigate the operational and environmental implications of decisions, and engage in other testing and training to mitigate risk.

NASA Response: In January 2022, NASA published a transition plan that includes several of the elements highlighted by the ASAP, "International Space Station Transition Plan." The plan was updated for publication in 2024 and intended a broader external stakeholder engagement around it. NASA agrees with the need to develop the details of the transition to a higher level of fidelity and continues to work with ASAP to develop and communicate the additional elements requested by the Panel in the recommendation. Much of the work highlighted by the ASAP recommendation has already begun, including increased definition of use of LEO platforms to support the Moon to Mars architecture, and will continue to evolve during this developmental stage of the commercial LEO economy. However, currently, NASA does not have a well-articulated plan and supporting budget to achieve the strategy.

This recommendation is **OPEN**.

2021-05-01: Development of Agency Strategic Vision for the Future of Space Explorations and Operations

Finding: For NASA to continue its trajectory of success in the decades ahead, it must proactively plan for and manage its work in the presence of the numerous challenges, constraints, and risks inherent in the changing environment of the aerospace community.

Recommendation: NASA should develop a strategic vision for the future of space exploration and operations that encompasses at least the next twenty years, including potential alternative scenarios, that is driven by how the Agency is going to understand and manage risk in the more complex environment in which it will be operating.

- The vision should describe the role that NASA intends to play during that period and how it plans to engage with both commercial and international partners.

- NASA should assess the workforce, including the number, types, skills, experience, and responsibilities that will be required, and the infrastructure facility requirements, with a plan for managing changes needed to meet those requirements.
- NASA should also propose general criteria for evaluating "make, manage, or buy" decisions on future programs or projects.
- All aspects of the strategic vision and its implementation should be clearly and unambiguously communicated throughout the Agency.

Rationale: NASA is no longer the sole driver or customer for human space flight capabilities and related technology, nor is it the sole organization creating demand. NASA, however, still has a critical role and responsibility in the space sector, and the Agency's decisions, opinions, and direction have weight and merit in the industry and across the globe. Consequently, it is imperative for NASA leaders to establish a clear vision of the future and an understanding of the Agency's purpose to anchor its decisions today and tomorrow. A strategic vision, and a set of guiding principles—clearly communicated to NASA's workforce and stakeholders—will help the Agency navigate the new environments within which it must operate to execute Government missions. In addition, such a top-down, strategically driven approach can expose and enable the organization to anticipate risks that otherwise might go unknown or unforeseen through an organic bottoms-up approach.

NASA's Response: NASA concurs with the recommendation and appreciates the ASAP communicating its concerns regarding the need for an Agency Strategic Vision, as indicated in the ASAP recommendation submitted to the Agency in December 2021. Since that time, the Agency has committed substantial time and effort to buying down risks by defining the role that it intends to play in the future and its strategies for a thriving NASA in 2040. Significant endeavors in support of this recommendation included publishing two foundational documents last year, the NASA Strategic Plan 2022 and the Moon to Mars Objectives; developing the Mission Support infrastructure Agency Master Plan, assessing the workforce strategy; implementing Technology Roadmaps; and holding a number of Agencywide leadership brainstorming sessions as well as internal and industry-wide "Futures Roundtable" events. NASA has kept ASAP apprised of its work in the important areas of strategic planning at regular intervals. Most recently, the NASA Deputy Associate Administrator and Agency leadership briefed the Panel members at the ASAP 2nd Quarterly Meeting in May 2023. The Agency will continue to work on this recommendation and keep the ASAP abreast of its progress.

This recommendation is **OPEN**.

2021-05-02: Establishment of an Agency "Board of Directors"

Finding: Over the decades, at various times with varying amounts of success, NASA leadership has sought to create an Agencywide identity to foster greater coordination. There remains, however, a very strong and separate culture at each NASA Center, which drives the Centers to prioritize their own goals rather than those of the overall Agency. In turn, this creates pressure against the implementation of a strategic approach that aligns the whole organization to a common set of goals. Importantly, moreover, the resource flow remains Center-focused rather than optimized around integrated outcomes.

Recommendation: As a part of an overall risk management approach and in order to develop and execute its strategic vision for the future of space exploration, NASA should establish and provide leadership through a "board of directors" that includes the Center Directors and other key officials, with the emphasis on providing benefit to the Agency's mission as a cohesive whole, and not to the individual components of the Agency. The Board should act to identify the strategic risks and obstacles that NASA may encounter in executing its mission, evaluate Agency-level mitigation approaches, and align the efforts of all Centers to ensure desired outcomes.

Rationale: Although NASA has well-established executive management forums through which it deliberates various Agency decisions, it does not convene senior leaders as a strategic team with a holistic perspective on the Agency. Thus, the Panel recommends the Agency adopt a "Board of Directors"–like governance approach for its executives. Under this construct, the Administrator's most senior staff at Headquarters and the Center Directors would comprise an Agency steering committee with a deliberate Agency-level focus, rather than as representatives from and advocates for their areas of responsibility or Field Centers.

NASA could convene this team in various ways, but it need not be a new or separate forum. Rather, NASA should set different engagement expectations for these leaders when they meet, in that they should "leave their individual program and/or Center hats at the door" and focus on corporate-level challenges, opportunities, and decisions driven by the best interests of the Agency and its ongoing missions. This imperative to focus on the entirety of the enterprise can help support the tough resource decisions necessary to contend effectively with the challenges of stakeholder demands, inevitable schedule pressures, and budget constraints. With NASA's critical resources, workforce, and infrastructure largely managed at Field Centers incentivized to protect them, the Agency has struggled for many years to shift the workforce out of less critical work, or to divest obsolete facilities and infrastructure. This has added cost and manpower pressures to Field Centers that need margin for higher-priority work, innovative solutions, and new opportunities. To escape the status quo (i.e., protecting budget, preserving the workforce configuration, maintaining every building and piece of major equipment) an explicit shift to an Agency-level focus is an essential start to reducing fixed costs and freeing more resources for new work in space exploration.

NASA's Response: NASA concurs with the intent of the recommendation to ensure that implementation of a strategic vision for space exploration is conducted as a cohesive whole, and not on individual components of the Agency, and with the intent that strategic risks and obstacles need to be identified, managed, and

mitigated. However, NASA does not concur that a new Board structure is required, as the current Agency Governance System and its supporting processes, as well as informal senior leadership coordination, provide the structure needed to achieve the intended results. Based on the recommendation, NASA will implement several specific improvements to ensure a strategic focus is maintained, that leaders continue to act as the "Board of Directors" in these existing meetings, and that the approach towards enterprise risks focuses on outcomes rather than tracking.

This recommendation is **OPEN**.

2019-02-01: Required Transition to Next Generation Extravehicular Mobility Units (EMUs)

Finding: The ASAP has become increasingly concerned with the risk posture that NASA has adapted regarding the current EMUs used in International Space Station (ISS) operations and has concluded that the current EMUs are now outside their design life.

Recommendation: NASA should begin an immediate transition to a new-generation Extra-Vehicular Activity (EVA) suit system EMU, before the risk to EVA becomes unmanageable.

Rationale: It is an undeniable fact that the 40-year-old EMUs used in ISS operations are reaching the end of their useful life. The Panel reviewed the increasing challenges of difficult upgrade efforts, loss of component vendors over time, lack of critical refurbishment parts, and life extension analyses that will grow in uncertainty as the suit hardware continues to age. Over the years, the Panel has commented on the highly innovative and often heroic approach that NASA has taken to devise EMU component upgrades and suit life extensions. The Panel has also noted the small but productive steps accomplished by the development program for the next-generation xEMU prototype. The current plan is to extend today's EMU use to 2028; however, it is increasingly apparent that the usable life of the current EVA suits is limited. The Panel encourages NASA to step back from day-to-day management issues to view this urgent issue from a broader, more holistic outlook. The problem does not lie simply in the fact that the suits are old; but the fact that manufacturers of several critical suit components, including the very fabric of the suits, have now gone out of business, creates real urgency for transitioning to new EVA suit systems. New suits are needed not only for future space exploration, but also for its current space activities. NASA cannot maintain the necessary, ongoing low-Earth orbit operations without fully functional EVA suits.

NASA's Response: In 2023, NASA had executed its acquisition for an EMU flight suit that provided the flexibility to support both the lunar mission as well as a replacement for the current EVA suits that are much needed for the ISS mission. ASAP viewed this as a good advancement; however, in 2024, the program

suffered a setback. The contractor withdrew from the contract, leaving NASA without a developer for the next-generation ISS EMU. The Panel awaits an updated EMU program brief in 2025 and an updated NASA response to this recommendation.

This recommendation is **OPEN**.

2015-05-02: Human Space Flight Mishap

Finding: The CCP is now developing a formal plan for how it will respond in the event of a major malfunction or mishap. In addition to optimizing what can be learned by proper investigation of malfunctions or mishaps, this plan must comply with the specific language in the NASA Authorization Act of 2005 concerning Human Space Flight Independent Investigations. NASA has tentatively identified the entities that would investigate various types of mishaps during the five mission phases. Under the current Authorization language, a Presidential Commission would be required in all cases involving loss of the flight crew as well as in all cases involving loss of the vehicle, even if the flight crew is not injured. Use of a Presidential Commission in the latter cases appears excessive.

Recommendation: 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.

Rationale: The requirement for a Presidential Commission was logical for the International Space Station (ISS) or Space Shuttle missions because they were reusable national assets. It would, however, appear excessive in some cases for commercially provided vehicles or other vehicles not planned for reuse. One example would be the sinking of a non-reusable vehicle after the flight crew had been safely recovered and were on their way home.

NASA's Response: NASA originally responded on April 30, 2016, concurring with the recommendation. The response stated that NASA was reaching out to the Federal Aviation Administration (FAA) and the National Transportation Safety Board to jointly develop viable options to revise the Authorization language with today's systems in mind. NASA provided a follow-up response on March 20, 2017, in which they provided the results of NASA's assessment of strategy options in the event of a major malfunction or mishap in the Commercial Crew Program (CCP). The ASAP provided a written response on September 8, 2017, followed by subsequent discussions during which the ASAP provided alternate solutions to which NASA provided a third response on March 15, 2018. NASA and the Congress are still working to establish a satisfactory process to address the concerns previously articulated. The ASAP believes action is increasingly essential and urgent

as NASA has already begun launching astronauts on commercially provided vehicles, and the future Artemis missions will be even more complex in their involvement of commercial providers and international partners.

This recommendation is **OPEN**.

Appendix B

Aerospace Safety Advisory Panel Recommendations Closed in 2024

2022-05-01: Define an International Space Station (ISS) Deorbit Plan

Finding: Although discussions are ongoing between NASA and the Russian Space Agency (RSA) to make the controlled deorbit plan more robust, the ASAP reiterates its concern first stated in 2012, about the lack of a well-defined, fully funded controlled reentry and deorbit plan for the ISS that is available on a timeline that supports the planned ISS retirement. Furthermore, the Panel recognizes that the ISS partners are operating at risk, today, without the capability to deal with a contingency situation that would lead to a deorbit. The risk to public safety and space sustainability is increasing every year as the orbital altitudes in and around the ISS continue to become more densely populated by satellites, increasing the likelihood that an unplanned emergency ISS deorbit would also impact other resident space objects.

Recommendation: NASA should define an executable and appropriately budgeted deorbit plan that includes implementation on a timeline to deliver a controlled reentry capability to the ISS as soon as practicable—to be in place for the need of a controlled deorbit in the event of an emergency as well as in place before the retirement of the ISS—to ensure that the station is able to be deorbited safely.

Rationale: The Panel had a previous recommendation, 2021-01-02, "ISS Deorbit Capability," which stated:

> **Recommendation:** (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.
>
> **Rationale:** An unexpected, emergency event could precipitate the need to deorbit the ISS at any time. Timely development of the plan on how to respond to such a situation before it occurs will allow an optimum response and maximize the safety to the public in such a situation.

The ASAP closed the recommendation in 2020 because there was conceptual agreement on an approach and a final agreement was imminent. Subsequent detailed discussions among the ISS partners have identified technical and operational issues which need further addressing, so the Panel is returning to this topic. The urgency, first highlighted in 2012, remains.

Closure Rationale: As of June 2024, NASA funded a contract with SpaceX to provide a USDV to support an ISS End of Life (EOL) timeline of 2030. The SpaceX USDV design is a modified version of the cargo Dragon vehicle, and the proposed development timeline appears reasonable to meet the required launch date of mid-2029. NASA has also made good progress addressing an emergency ISS deorbit capability prior to USDV arrival and has an ISS Contingency Deorbit Protocol in place outlining a high-level strategy. Additionally, the ISS program will maximize ISS propellant deliveries to ensure propellant availability for contingency orbit reserve. Given the release of the USDV contract and that NASA has plans to accommodate controlled ISS deorbit for emergency scenarios, the Panel believes NASA's response to the recommendation will significantly lower the risk to the public for both planned and emergency ISS deorbit scenarios.

This recommendation is **CLOSED**.

2020-03-01: Designation of a Lead Federal Agency for Civil Space Traffic Management (Congress)

Finding: For several years, the Panel has expressed concern with the risk of damage to orbiting spacecraft and transiting astronauts due to micrometeoroids 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 predictions for both commercial crew vehicles and Orion, and it has been a factor in two of the top safety risks for the International Space Station (ISS). NASA declared it an Enterprise Risk in 2017.

Recommendation: The Panel recommends that the Congress:

- Designate a Lead Federal Agency for Civil Space Traffic Management.
- Provide that agency with authority, immunity from lawsuits, and resources to do the job.
- In addressing the Space Traffic Management issue, require whole-of-government engagement; public-private partnerships; and collaboration between government, industry, academia, and the international community.

Rationale: The hazard persists and continues to grow exponentially. Space is becoming more congested. For example, CubeSats and other small satellites are being launched with increasing frequency, and several companies are now deploying mega-constellations with hundreds, or even thousands, of satellites. Some of these satellites incorporate the use of electric propulsion and autonomous onboard maneuvers with very short turnaround times, increasing the difficulty of tracking and planning for collision avoidance.

It is important to recognize the prevalence of the issue. Orbital debris events and close calls are not rare, but they are in fact becoming more and more frequent as space becomes more congested and as national and international space players—who rightfully seek to leverage the high ground of space for commerce, science, and national prestige—continue to populate the space domain with new satellites. The risks are growing, and a more strategic approach to the problem is now necessary to arrest the risks and to assure that the domain of space remains sustainable.

NASA currently has twenty missions in low-Earth Orbit (LEO), and the Agency takes the risk seriously. But the issue is larger than NASA—it affects and is affected by all entities that conduct operations in space, and it endangers all those functions on which the public has come to rely—communications, navigation, weather prediction, to just start the list. While the ASAP is principally focused on the serious hazards to NASA spacecraft and astronauts, the Panel recognizes that the issue must be tackled on a broader format.

The Panel was encouraged in 2018 when the National Space Council issued Space Policy Directive-3 (SPD-3), the National Space Traffic Management Policy, which acknowledged and addressed this issue and the need to improve Space Situational Awareness and Space Traffic Management. SPD-3 promoted the implementation of a number of steps to address the orbital debris risk and recommended that the Department of Commerce take responsibility for implementing a Civil Space Traffic Management framework. The Panel is dismayed that Congress and the Administration have not yet reached an agreement on the appropriate response to that recommendation, resulting in departments and agencies not being able to move forward on implementing a framework that will both materially reduce the Space Traffic Management risks and increase the sustainability of space as an international strategic domain.

It is well overdue that the United States exert some effective international leadership in the safety of space operations and begin doing so by designating—including providing authority and resources to—a lead agency to see to the provision of timely and actionable safety data to all space operators; work proactively within government, with industry, and in partnership with the international community in developing standards, guidelines, best practices, and "rules of the road" for safe space operations; and support the conduct of scientific research and technology development for related areas, such as improved sensors, software, constellation management techniques, and methods for active debris management.

Closure Rationale: In July 2022, the White House issued the National Orbital Debris Mitigation Plan, which detailed numerous tasks and responsibilities across the government (including NASA) to proactively address orbital debris challenges. Subsequently, with a supporting budget from Congress, the Department of Commerce Office of Space Commerce (OSC) developed a long-term strategy to manage civil space traffic, including conjunction assessments and warning of orbital debris. Congress has assigned resources at a level that allows the OSC to develop operational capabilities and coordinate among national and global partners. Transition of responsibilities for civil space traffic management from the Department of Defense is currently in work and due to be completed in the next year. Key to the OSC's strategy is the development of operational improvements beyond the status quo that substantially reduce the risks of orbital debris, although continued Congressional funding is necessary to grow the capabilities beyond basic functionality.

This recommendation is **CLOSED**.

Appendix C

Aerospace Safety Advisory Panel Members

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

- Chair, Aerospace Safety Advisory Panel
- Former Commander, Joint Functional Component Command for Space, US Strategic Command, and 14th Air Force, Air Force Space Command
- Former Commander, 45th Space Wing, Cape Canaveral, Florida
- Former NASA Astronaut
- Former Air Force Flight Test Engineer

Lieutenant General Susan J. Helms, USAF (Ret.), is currently an independent consultant and the Principal of Orbital Visions, LLC. She has served on several boards, including the Board of Trustees for The Aerospace Corporation, and is a member of the National Academy of Engineering.

General Helms has almost thirty-six years of military service in the USAF. In her last assignment, she was Commander of the 14th Air Force, Air Force Space Command, and Commander of the Joint Functional Component Command for Space, US Strategic Command at Vandenberg Air Force Base in California. As the leader of the USAF'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 of the 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 USAF 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 of Patrick Air Force Base at Cape Canaveral, Florida, and served as the J5 of the US 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 US military woman in space. She flew on STS-54 (1993), STS-64 (1994), STS-78 (1996), and STS-101 (2000), and she served aboard the ISS 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. She was inducted into the Astronaut Hall of Fame in 2011.

Mr. William P. Bray

- Former Vice President, Strategic Business Operations, Frontier Technology Incorporated
- Former Deputy Assistant Secretary of the Navy for Research, Development, Test and Evaluation (DASN RDT&E)
- Former Executive Director, Navy Program Executive Office (PEO) for Integrated Warfare Systems (IWS)
- Former Director for Integrated Nuclear Weapons Safety and Security at Navy Strategic Systems Program, Direct Reporting Program Management

Mr. William P. Bray is currently the Principal Consultant and owner at W.P. Bray Consulting, providing independent consultant services to the defense and aerospace acquisition and engineering community. From February 2021 to August 2022, he served as the Vice President for Strategy and Business Operations at a defense data analytics company.

Prior to that, Mr. Bray retired in October 2020 after thirty-six years of government service, the last fourteen years serving in the Senior Executive Service (SES). His last assignment was as the Deputy Assistant Secretary of the Navy (DASN) for Research, Development, Test and Evaluation (RDT&E) under the Assistant Secretary of the Navy (ASN) for Research Development and Acquisition (RD&A). In that role, Mr. Bray was responsible for executive oversight of all matters related to Naval RDT&E Budget Activities, Science and Technology, Advanced Research and Development, Prototyping and Experimentation, Systems Engineering, and Test and Evaluation. In addition, he was responsible for oversight and stewardship of the Department of Navy Research and Development Establishment which included all Naval Laboratories, Warfare Centers, and Navy University Affiliated Research Centers.

Prior to the DASN RDT&E position, Mr. Bray was the Executive Director for PEO Integrated Warfare Systems (IWS), where he directed the acquisition and Fleet support of the Surface Navy's combat systems, weapons, radars, and related international and foreign military sales programs. Other leadership roles within the Navy included the Director, Integrated Nuclear Weapons Safety and Security at the Navy Strategic Systems Programs Office, and Major Program Manager (MPM) for Surface Navy Combat Systems. Mr. Bray started his career at the Naval Surface Warfare Center, Corona Division, Corona, California, in December 1984.

Mr. Bray graduated from The Pennsylvania State University in 1984 with a B.S. degree in Petroleum and Natural Gas Engineering and earned an M.S. degree in Systems Management from the University of Southern California. He was a member of the defense acquisition workforce and certified at Defense Acquisition Workforce Improvement Act (DAWIA) Level III in Program Management, Systems Engineering, and Test and Evaluation. During his government career, he received a Meritorious Executive Presidential Rank Award in 2018, the Navy Distinguished Civilian Service Award in 2017 and 2020, and the Navy Superior Civilian Service Award in 2013.

Dr. Amy Donahue

- Provost and Chief Academic Officer, United States Coast Guard Academy
- Professor emeritus of Public Policy, University of Connecticut (UConn)
- Former Senior Advisor to the Administrator for Homeland Security at NASA

Dr. Amy Donahue is Provost and Chief Academic Officer at the United States Coast Guard Academy. She is responsible for the quality and effectiveness of the Academy's academic enterprise in support of its core mission to educate leaders of character who serve as officers in the Coast Guard. Dr. Donahue is also professor emeritus of public policy at the University of Connecticut (UConn). As a social scientist, her research has focused on executive leadership, homeland security, and disaster preparedness.

From 2011 to 2018, Dr. Donahue served as the UConn's Vice Provost for Academic Operations and Chief of Staff to the Provost. As part of a small team of executive leaders, she was a key partner in developing the $1.7 billion Next Generation Connecticut program, crafting the University's academic vision, guiding program development to support excellence in teaching and learning, preparing the University for reaccreditation, and building a new regional campus.

Previously, Dr. Donahue headed UConn's Department of Public Policy. She also advised the Chancellor of Louisiana State University (LSU) immediately following Hurricane Katrina and was the founding director of LSU's Stephenson Disaster Management Institute. She was principal investigator on research funded by the Department of Homeland Security as part of the Center of Excellence for the Study of Natural Disasters, Coastal Infrastructure and Emergency Management.

From 2002 to 2004, Dr. Donahue was Senior Advisor to the Administrator for Homeland Security at NASA. In 2003, she had a major leadership role in the field response to the crash of Space Shuttle Columbia. From 2004 to 2007, Dr. Donahue

served on the Aerospace Safety Advisory Panel. She was reinstated to the Panel in 2021.

As the Distinguished Military Graduate of Princeton's Reserve Officer Training Corps in 1989, she began her career serving in the US Army on active duty in the 6th Infantry Division at Fort Wainwright, Alaska. Her military assignments included serving as Officer in Charge of a Forward Surgical Team; as the Training and Operations Officer (S3) for the 706th Main Support Battalion; and as Chief of Mobilization, Education, Training, and Security for Bassett Army Hospital.

Dr. Donahue holds her Ph.D. in Public Administration and her Master of Public Administration (MPA) from the Maxwell School of Citizenship and Public Affairs at Syracuse University. She graduated magna cum laude with a B.A. in Geological and Geophysical Sciences from Princeton University. She was elected a fellow of the National Academy of Public Administration in 2011. She is certified as a Wilderness Emergency Medical Technician.

Mr. Paul Sean Hill

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

Mr. Paul Sean Hill is a speaker and consultant focused on creating and leading high-performing teams in any industry. He also is a Director of the Manned Spaceflight Operations Association, chaired NASA's Orion Thermal Protection System Independent Review Team, and is the author of *Leadership from the Mission Control Room to the Boardroom* and *The Last Butterfly*.

During his twenty-five years at NASA, he first developed Space Station construction techniques and then led flights from Mission Control as a Space Shuttle and ISS Flight Director. He supported twenty-four 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, Mr. Hill 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, Mr. Hill served in the USAF in military satellite operations. He earned his Bachelor 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.

Ms. Katharina McFarland

- Vice Chair of the Army Science Board
- Director of SAIC Board of Directors
- Director of Transphorm Board of Directors
- Former Chairman and current member of the Board of Army Research and Development at the National Academies of Science

Ms. Katharina McFarland, with over thirty years of government service, is widely recognized as a leading subject-matter expert on government procurement. From 2012 to 2017, she was the Assistant Secretary of Defense for Acquisition, as well as acting Assistant Secretary of the Army for acquisition, logistics, and technology from 2016 to 2017. She was President of the Defense Acquisition University from 2010 to 2012. From 2006 to 2010, Ms. McFarland was the Director of Acquisition for the Missile Defense Agency. She is an accredited materials, mechanical, civil, and electronics engineer. She has received an Honorary Doctoral of Engineering from the University of Cranfield, United Kingdom; the Presidential Meritorious Executive Rank Award; the Secretary of Defense Medal for Meritorious Civilian Service Award; the Department of the Navy Civilian Tester of the Year Award; and the Navy and United States Marine Corps Commendation Medal for Meritorious Civilian Service. Ms. McFarland has substantial experience with the US Department of Defense, Department of Army, and intelligence community procurement with focuses on space applications, artificial intelligence, cyber, and informational technologies in defense acquisition, program management, logistics, and technology.

Mr. Charlie Precourt

- Former Vice President and General Manager, Northrop Grumman
- Former NASA Astronaut
- Retired USAF Colonel, Fighter Pilot, and Test Pilot

Mr. Charlie Precourt currently serves as a director on several boards and consults in a variety of aerospace activities, including director with the National Business Aviation Association, the Experimental Aircraft Association, World View, Inc., the American Center for Manufacturing and Innovation, and the Astronaut Scholarship Foundation. He was appointed to NASA's Aerospace Safety Advisory Panel in 2023.

Mr. Precourt led the solid rocket motor propulsion business at Northrop Grumman, having joined the company in 2005 and retired in 2021. In that capacity, he oversaw a workforce of 3,500 employees in engineering, manufacturing, and program management with a portfolio including NASA's Space Launch System, the US Navy Trident D5, the USAF Sentinel and Minuteman Nuclear Missile systems, propulsion for DoD's satellite launch vehicles, and two new hypersonic missile programs that are a national priority.

Mr. Precourt joined Northrop Grumman following a fifteen-year career with NASA where he was as an astronaut and a program manager in the Senior Executive Service. He was qualified as an astronaut in 1991 and is a veteran of four Space Shuttle missions, serving as pilot and commander. After piloting Atlantis for the first docking with the Russian Mir Space Station in 1995, he gained extensive experience working with the Russian Space Agency and was appointed Director of Operations for NASA at the Gagarin Cosmonaut Training Center in Star City, Russia. From 1998 through 2002, he was Chief of NASA's Astronaut Corps, responsible for the selection, training, and mission certification of all Space Shuttle and International Space Station crews. Mr. Precourt was later appointed Deputy Program Manager for the International Space Station, responsible for the day-to-day management of ISS operations, on-orbit assembly, and the interfaces with NASA contractors and the ISS International Partners in Europe, Canada, Russia, and Japan. He was inducted into the US Astronaut Hall of Fame in 2012.

Mr. Precourt entered USAF active duty upon commissioning from the US Air Force Academy in 1977 and completed Pilot Training in 1978. From 1981 to 1984, he was an F-15 pilot and flight commander at Bitburg Air Base in Germany. He then attended the USAF Test Pilot School at Edwards AFB and served as a test pilot on the F-15E developmental test program and later as an instructor at the USAF Test Pilot School. He served twenty-three years in the US Air Force, retiring as a Colonel.

A native of Hudson, Massachusetts, Mr. Precourt received a Bachelor of Science degree in aeronautical engineering from the United States Air Force Academy in 1977, having also attended the French Air Force Academy in 1976 as part of an exchange program. He earned a Master of Science degree in engineering management from Golden Gate University in 1988 and a Master of Arts degree in national security affairs and strategic studies from the United States Naval War College in 1990.

Mr. Kent Rominger

- Former Vice President of Strategic Programs at Northrop Grumman Propulsion Systems
- Former NASA Astronaut
- Former Navy Fighter and Test Pilot

Mr. Kent Rominger held numerous positions at Northrop Grumman, Orbital ATK, and ATK over a fifteen-year period from 2006 to 2022. These positions included the director of Missile Programs; the vice president and capture lead for the OmegA launch system; and the vice president of Strategic Programs with responsibility for the Navy's Fleet Ballistic Missile Program, the USAF's Ground Based Strategic Deterrent pursuit, and Minuteman II Sustainment. He also served as vice president of Strategy and Business Development for Propulsion Systems and as vice president of Propulsion Systems' Test and Research Operations. Mr. Rominger joined Northrop Grumman (ATK) in October 2006 as vice president of Advanced Programs following distinguished careers with NASA and the US Navy.

Mr. Rominger was selected as a NASA astronaut in 1992. A veteran of five Space Shuttle flights, including two as the mission commander, he has logged over 1,600 hours and traveled almost 27 million miles in space. He culminated his NASA career as the Chief of the Astronaut Office and was selected into the US Astronaut Hall of Fame in 2015.

Mr. Rominger was commissioned as a naval officer in 1979. During his twenty-six-year career, he served as an F-14 Tomcat pilot with fighter squadrons VF-2 and VF-211 and as a Navy test pilot. While with VF-211, he completed a deployment to the Arabian Gulf during Operation Desert Storm. He is a graduate of the Navy Fighter Weapons School (Top Gun) and the Naval Test Pilot School at Patuxent River, Maryland. He has logged more than 8,500 flying hours in thirty-five different types of aircraft and has completed 685 carrier landings.

A native of Del Norte, Colorado, Mr. Rominger received a bachelor's degree in civil engineering from Colorado State University and a master's degree in aeronautical engineering from the US Naval Postgraduate School.

Dr. Mark N. Sirangelo

- Scholar in Residence at the University of Colorado
- Founding Executive and Former Head of Sierra Nevada Space Systems
- Founding Member and Past Chairman of the Commercial Spaceflight Federation
- Most Recent Past Chairman of the DoD Defense Innovation Board

Dr. Mark N. Sirangelo currently is the Scholar in Residence at the University of Colorado. He is also on the Tuskegee University Aerospace Advisory Board and is a visiting professor at Syracuse's Maxwell School of Citizenship and Public Affairs. Dr. Sirangelo has over a two-decade industry executive aerospace and space career, having led teams which have successfully managed billions of dollars of programs for over 300 programs and missions. In addition, he provides industry advisory services through his company QS Advisors, LLC.

In the space industry, he was the founding executive and head of Sierra Nevada Space Systems for over 10 years until 2018. Previously, Dr. Sirangelo was the Chairman and Chief Executive Officer (CEO) of SpaceDev, a publicly traded commercial space company that he grew from an early stage until its merger with Sierra Nevada Corporation (SNC). SpaceDev and SNC had many space firsts, including the inaugural winning XPRIZE team and the design, build, and operation of the first small satellite constellation. He was a past Chairman of the Commercial Spaceflight Federation, has been inducted as a Fellow of the American Institute of Aeronautics and Astronautics, and has served on the executive board of the Aerospace Industries Association.

Dr. Sirangelo served for three years as the Chief Innovation Officer of the State of Colorado. He is the most recent past Chairman of the US Department of Defense's Defense Innovation Board, providing advice to the office of the Secretary of Defense and the founding and past Chair of the DoD's Space Advisory Committee. Previously, he completed an assignment as Special Assistant to the NASA Administrator helping to develop NASA's return to the Moon.

Dr. Sirangelo and his organizations have been recognized with numerous corporate awards. These include being inducted into the Space Foundation's Technology Hall of Fame and the World's Top 10 Innovative Space Companies by Fast Company, being named Manufacturer of the Year by ColoradoBiz magazine, The Best Place

to Work by the Denver Business Journal, Inc. Magazine's top 200 companies, and Defense Industry's Fast Track 50, and being selected as a finalist in Ernst & Young's Entrepreneur of the Year.

One of the ways Dr. Sirangelo gives back to the space industry is as the founder and Chairman of eSpace, a nonprofit that supports the start-up and growth of space technology companies. As a personal passion, he has worked to make the world a safer place for children as a founding Board member of the National Center for Missing and Exploited Children (NCMEC), which resolved over 100,000 missing children's cases to date.

Dr. Sirangelo has a multifaceted personal background, including being a long-term licensed pilot and a successful creative artist. He holds a Bachelor of Science, Master's in Business Administration, and Doctorate-level degrees and has served his country proudly as a US Army officer.

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

- Medical Consultant, Virginia Department of Health
- Former Senior Aviation Medical Examiner, Federal Aviation Administration
- Former NASA Chief Health and Medical Officer

Dr. Richard S. Williams is a general surgeon and aerospace medicine physician who currently serves as a Medical Consultant in the Virginia Department of Health. His duties include providing medical consultation services to Virginia public health districts without a physician on staff and serving as a consultant for the Medical Director, Community Health Services, Virginia Department of Health. Dr. Williams is also a former FAA Senior Aviation Medical Examiner and still provides aeromedical consultation services for all classes of airmen on request. Previously, he served as NASA's Chief Health and Medical Officer. He spent 27 years in the US Air Force (USAF) as a general surgeon, flight surgeon, and medical manager and leader, domestically and in contingency operations abroad.

Dr. Williams was assigned 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 ISS 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 fifteen-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, as well as an MD degree in 1979 and a Master of Public Health (MPH) degree in 1996, both 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 and decorations include the Bronze Star medal, the Meritorious Service Medal, 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 relevant to aerospace medicine.

Aerospace Safety Advisory Panel Staff Members

Ms. Carol Hamilton

- Aerospace Safety Advisory Panel Executive Director

Ms. Carol Hamilton, Executive Director of the ASAP since 2015, has specialized in system safety engineering for more than twenty-five 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 from 1991 to 2015, Ms. Hamilton contributed to more than twenty space flight missions, serving as a Senior System Safety Engineer for Hernandez Engineering for eight crewed Space Shuttle missions and later as the Project Safety Manager for fourteen uncrewed space missions. During her NASA career, Ms. Hamilton has been an instructor for the NASA Safety Training Center and has served on several NASA mishap investigation boards.

Ms. Lisa Hackley

- Aerospace Safety Advisory Panel Administrative Officer

Ms. Lisa Hackley has worked at NASA Headquarters for more than twenty-nine 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 as the ASAP Administrative Officer in May 2019, Ms. Hackley worked in OIIR's Export Control and Interagency Liaison division for fifteen years, including a voluntary secondment to the Federal Emergency Management Agency in late 2017 to assist with the hurricane relief efforts.

Ms. Ashley Mae, RN

- Aerospace Safety Advisory Panel Technical Writer

Ms. Ashley Mae is an accomplished technical writer with over a decade of experience, specializing in medical, scientific, and educational content. Holding a Bachelor of Science in Nursing (BSN) from Georgia Southern University and a Master of Science in Nursing Education (MSN-Ed.) from Western Governor's University, she has uniquely combined a strong academic foundation with extensive practical experience. Notably, she deployed as an emergency mobilization response nurse to New York City in April 2020, where she spent several weeks working in an epicenter Queens hospital providing care to COVID-19 patients during the height of the pandemic. Her profound understanding of healthcare practices, patient care, and medical procedures has been refined through hands-on experience in various healthcare settings.

Ms. Mae also possesses over five years of experience in nursing education, equipping her with a deep understanding of educational methodologies that enable her to translate complex medical and scientific concepts into comprehensive and accessible technical documentation. Now in her second year as the ASAP technical writer and editor for Tom & Jerry, Inc., she has honed her expertise in delivering high-quality, precise, and impactful documentation tailored to the needs of diverse audiences.

Currently, Ms. Mae is in the midst of her own battle with breast cancer, demonstrating resilience and determination while undergoing treatment. Her personal journey has further deepened her empathy and commitment to creating impactful content. Through her diverse background, she brings a unique blend of practical healthcare experience, pedagogical expertise, and profound personal insight to her technical writing, ensuring accuracy, clarity, and relevance in all written materials.

Front Cover: *(December 23, 2024) Artist's concept of the International Space Station.*

Back Cover: *(July 19, 2018) Artist's concept of the Boeing CST-100 Starliner in low-Earth orbit. (December 9, 2020) Photo taken by SpaceX of the Starship SN8 High-Altitude Flight Test.*

Aerospace Safety Advisory Panel

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Mr. William P. Bray
Dr. Amy K. Donahue
Mr. Paul Sean Hill
Ms. Katharina McFarland
Mr. Charles Precourt
Mr. Kent V. Rominger
Dr. Mark N. Sirangelo
Dr. Richard S. Williams

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