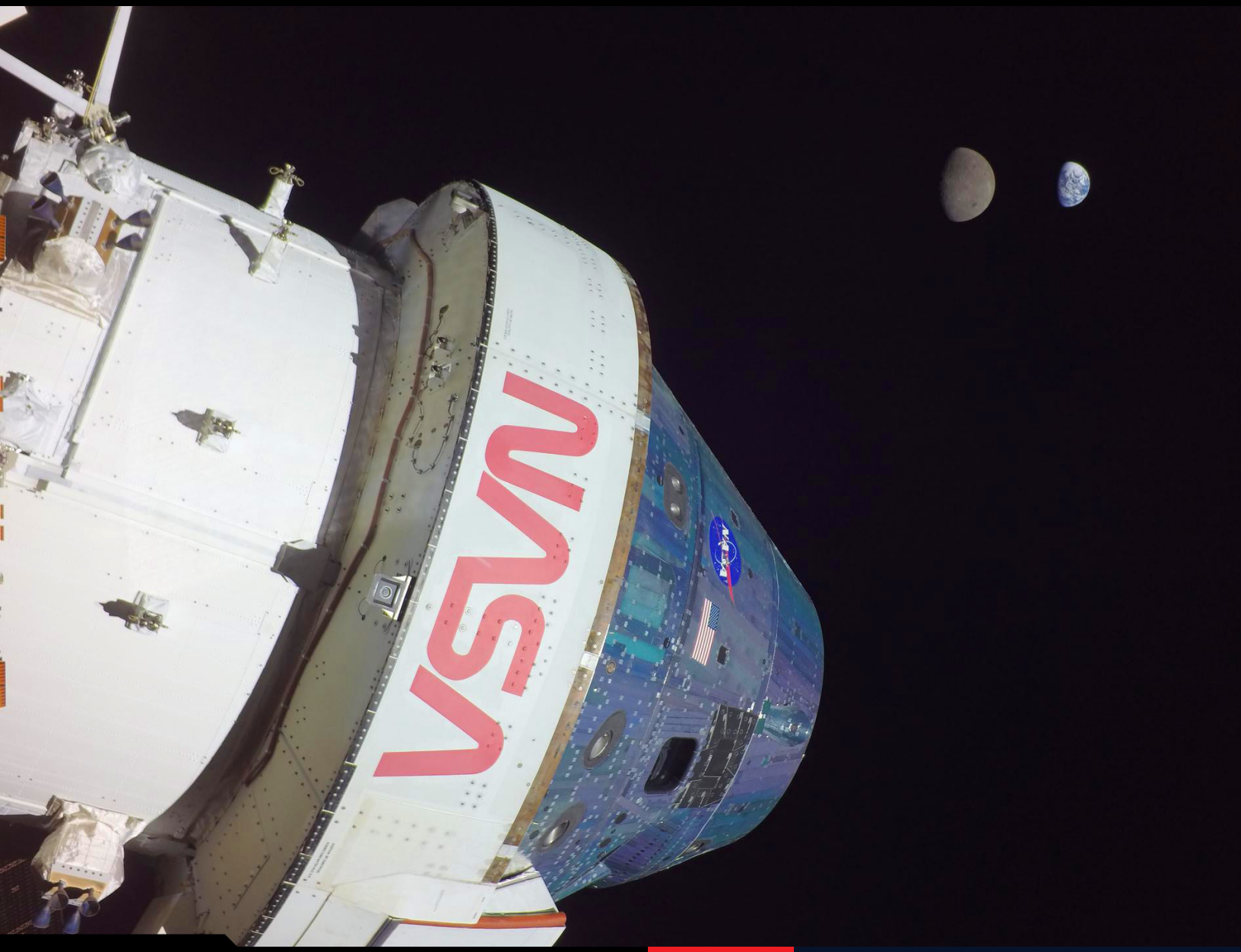
National Aeronautics and Space Administration



Aerospace Safety Advisory Panel

Annual Report

2023

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

January 1, 2024

The Honorable Bill Nelson
Administrator
National Aeronautics and Space Administration
Washington, DC 20546

Dear Senator Nelson:

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 2023 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 2023 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 made in 2022. 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. We acknowledge 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.

The report also addresses safety assessments for both the Moon to Mars Program and the operations, current and future, in Low-Earth Orbit. Additionally, it touches on relevant areas of human health and medicine in space, regulatory requirements for commercial space operations as they affect NASA, and the impact of budget constraints and uncertainty on safety.

I submit the ASAP Annual Report for 2023 with respect and appreciation.

Sincerely,

Patricia Sanders

Dr. Patricia Sanders
Chair, Aerospace Safety Advisory Panel

Enclosure

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

January 1, 2024

The Honorable Kamala Harris
President of the Senate
Washington, DC 20510

Dear Madam President:

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

January 1, 2024

The Honorable Mike Johnson
Speaker of the House of Representatives
National Aeronautics and Space Administration
Washington, DC 20546

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Enclosure

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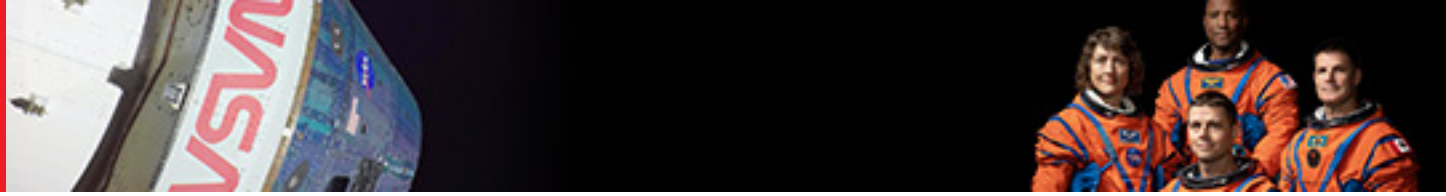
The Aerospace Safety Advisory Panel Charter and Quarterly Meeting Minutes can be found at https://oiir.hq.nasa.gov/asap/.



I. Preface

The Aerospace Safety Advisory Panel (ASAP or Panel) was established by Congress 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 makes insight visits to NASA Field Centers or other related sites. It reviews safety studies and operations plans and advises on hazards related to proposed or existing facilities and operations, safety standards and reporting, safety and mission assurance aspects of ongoing and proposed programs, and NASA management and culture issues related to safety. Although the Panel may perform other duties and tasks as requested by either the NASA Administrator or Congress, the ASAP members normally do not engage in specialized studies or detailed technical analyses.

This report highlights the issues and concerns the Panel identified during its activities over the past year. 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; discussions with NASA management, employees, and contractors; and the Panel members' expertise. The full text of the recommendation submitted to the Administrator during 2023 is included as Appendix A, along with the Panel's open recommendations from prior years. The recommendations the ASAP closed in 2023 are included in Appendix B.

II. Introduction and Overview

This report reflects the Panel's strong emphasis on strategic-level aspects of NASA leadership, risk management, and safety culture — which has been its primary focus over the past two years — while also giving attention to the tactical level of technical execution. The Panel believes 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 meaningful progress toward meeting the intent of the broad-ranging recommendations the Panel made in 2022. The Panel believes 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 its recommendations are ambitious and achieving them will demand considerable time and effort. That said, as the observations in this report reveal, NASA has made impressive progress. Challenges remain, however, and are highlighted within this report.

This report addresses safety assessments for both the Moon to Mars (M2M) Program and the operations, current and future, in low-Earth orbit (LEO). It will also touch on relevant areas of human health and medicine in space, regulatory requirements for commercial space operations as they affect NASA, and the impact of budget constraints and uncertainty on safety.

III. Continued Focus on Strategic Recommendations

A. Strategic Vision

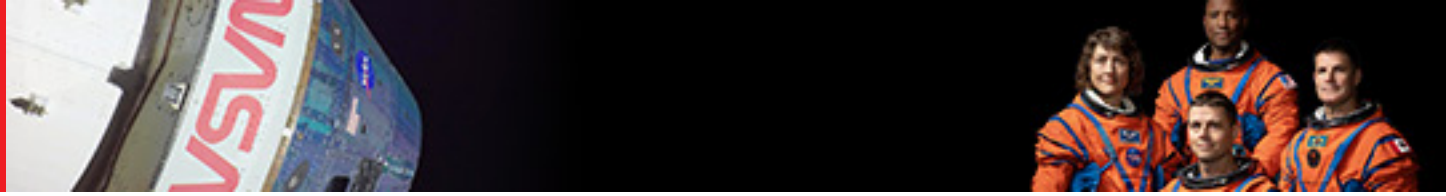
In the *ASAP Annual Report for 2021*, the Panel made the following recommendation:

Recommendation 2021-05-01: 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.

The Panel recognized that developing a strategic vision and implementing it across the Agency would be a challenging undertaking and did not expect immediate results. Over the past two years, however, NASA has developed and clearly communicated its Vision, Strategy, and Strategic Objectives across the Agency. Further, in 2023, the Agency started to develop the implementation and action plans necessary to operationalize the strategy. With admirable constancy of purpose and focus, very substantial progress has been made toward identifying core focus areas, objectives, and strategic action teams, and aligning the Agency to these initiatives. NASA is now progressing to identify and take the specific actions necessary to execute these strategic goals and initiatives throughout the Agency.

In assessing NASA's progress towards closure of this recommendation, the ASAP notes two areas with explicit safety and risk management implications that require some additional effort. These are: (1) Delivering the initial action plans and expected outcomes to operationalize the vision, strategy, and objectives to ensure essential technical and safety competency is retained within NASA, and (2) Exercising the Agency's acquisition and technical decision-making process and approach relative to "Make, Manage, or Buy" acquisition decisions to ensure systems engineering, programmatic, and safety concerns are assessed up front and early in the acquisition strategy maturation process.



1. Operationalizing the Strategy: *NASA 2040*

NASA 2040 is a new Agency-wide initiative to operationalize the Agency's vision and strategic objectives. As the driving force for operationalizing its strategic efforts, it is intended to generate the action plans across NASA Headquarters (HQ) and Centers that will align and execute the Agency's strategic objectives. Although titled *NASA 2040*, NASA does not intend that these objectives will take fifteen years to achieve. Rather, *NASA 2040* articulates the Agency's guiding intent, serving as a "North Star," to drive the identification of major goals and fundamental work the Agency needs to do *today* to achieve the vision of *tomorrow*.

As noted in **Figure A**, the Agency has identified seven distinct but interdependent workstreams to focus their efforts. These include Mission, Structure, Budget, People, Infrastructure, Technology, and Process. Each workstream has a dedicated team, composed of NASA HQ personnel, NASA Center leadership, and subject matter experts. Each team is progressing forward to deliver recommendations and implementation plans over the next six months. The Mission and Structure workstreams will deliver their first product around the time of the publication of this report.

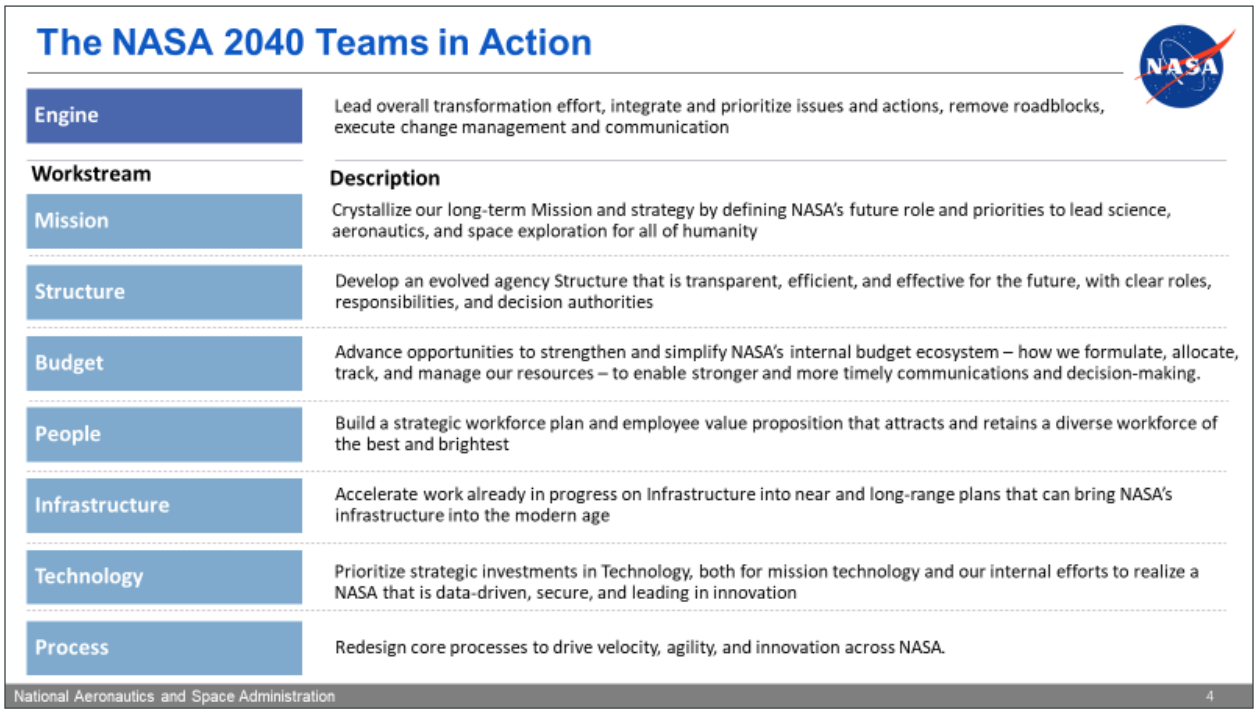


Figure A. NASA 2040 Workstreams

It is the Panel's view that the Agency leadership team is on track and, most importantly, having the appropriate strategic and risk management discussions within each of these workstream teams. The ASAP looks forward to seeing detailed implementation plans as they are delivered by these workstream teams, particularly the expected outcomes related to safety and risk management.

While encouraged by the *NASA 2040* strategic effort in these initial stages, this effort has an ambitious agenda and requires continuous and focused engagement from key leaders. Given this, the ASAP suggests the Agency keep its attention focused on results, outcomes, value-added activities, and to avoid letting bureaucratic processes overpower the product. Shared agreement on the goals and priorities is important, and accountability to execute them is critical. To support this, clear, consistent communication and broad organizational engagement will help ensure this work continues to be strategic and impactful. In the coming year, the Panel will seek evidence of measurable progress toward building a NASA that is ready to face the risk challenges of 2040.

2. Make, Manage, or Buy

One of the most salient strategic questions that arises about NASA's future is the appropriate composition of its workforce to meet the forward challenges. "Make, Manage, or Buy" decisions not only define significant acquisition strategies for large projects and programs, but also dictate the skill mix NASA's workforce will need to be able to guide those projects and programs development to operations.

The Panel notes that the Exploration Systems Development Mission Directorate (ESDMD) has adjusted their overall approach to acquisition to account for deliberation about "Make, Manage, or Buy" decisions. **Figure B** shows three critical milestone reviews that the ESDMD now has in their engineering and acquisition process milestones: (1) Architecture Concept Review (ACR); (2) Element Initiation (EI) Review; and (3) Mission Concept Review (MCR). The EI Review is a recent addition between the ACR and the MCR. This review should foster the right acquisition and technical dialogue much earlier in the process and aid the

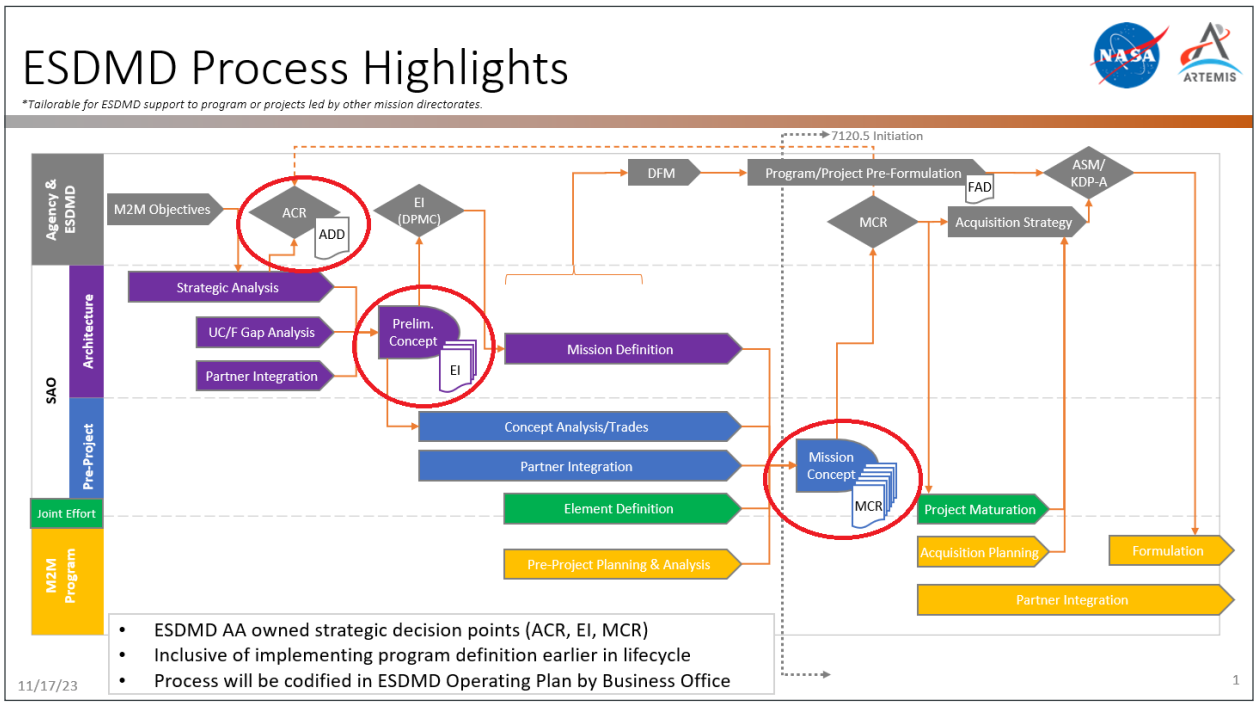
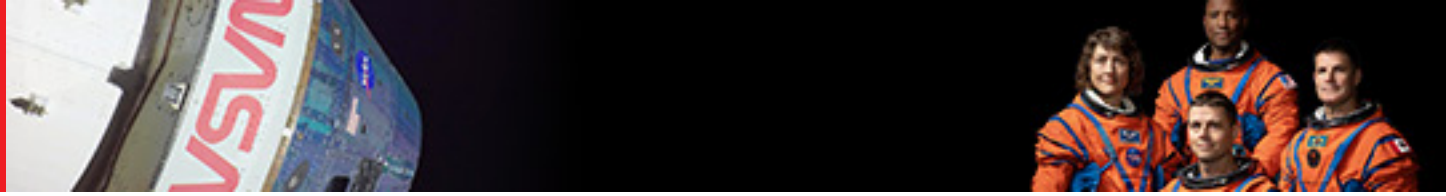


Figure B. ESDMD Technical and Acquisition Process & Milestones



Agency in determining the best acquisition approach for any new system or element brought into the Artemis architecture. Of note, ESDMD contends this process adjustment is tailorable for other Agency Directorates, Centers, programs, and projects and NASA should explore applying this approach and associated milestones as a potential best practice across the Agency.

The ASAP views these additional ESDMD milestones, and especially the EI Review, as positive steps in understanding the implications of "Make, Manage, or Buy" decisions and associated risks well in advance of determining and committing to the acquisition strategy for future architectural elements such as the lunar rover, lunar infrastructure, and others.

There is no doubt that a "Make, Manage, Buy" decision and the subsequent contracting approach for a particular element will impact many aspects of how NASA organizes and executes as well as its ability to deal with and mitigate the inherent programmatic, technical, and safety risks. As a consequence of any chosen acquisition strategy, several questions naturally arise:

- How are responsibilities defined between NASA and other entities of the development?
- How does the NASA Program Manager (PM) organize to best manage and execute the program safely and effectively?
- What are the core competencies and workforce size that NASA needs to execute their development efforts safely and competently, and how should the existing workforce best be shaped to accomplish this?
- What are the key infrastructure capabilities needed to execute? What inherent NASA infrastructure capabilities are no longer needed?
- How will the NASA PMs use or adapt existing Systems Engineering & Integration (SE&I) processes to retain consistent safety and risk management outcomes and culture within the development? Depending on the acquisition strategy, what new processes may be needed?
- What are the SE&I requirements and practices for the broader architecture, and how are diverse acquisition strategies managed to retain consistent risk management outcomes and culture?

As the Agency ponders these questions, the *NASA 2040* workstreams, as shown in **Figure C**, could provide an excellent framework to understand and assess risks and identify the actions that should be taken to align the organization to the acquisition strategy and further mitigate these risks. In addition, accountability to follow through on these actions is critical. As discussed in the next section, the Federated Board could serve as the appropriate leadership forum to reach agreement and monitor execution across these workstreams and the Agency.

In summary, the Agency continues to make progress on the strategic leadership recommendation and associated initiatives. With continued Agency leadership attention, focus, and commitment, their efforts should soon bear fruit. The Panel looks forward to seeing specific implementation plans with tangible actions and outcomes over the next year across each *NASA 2040* workstream. Particularly those which directly tie to safety and technical risk management such as workforce shaping, technical competency, engineering

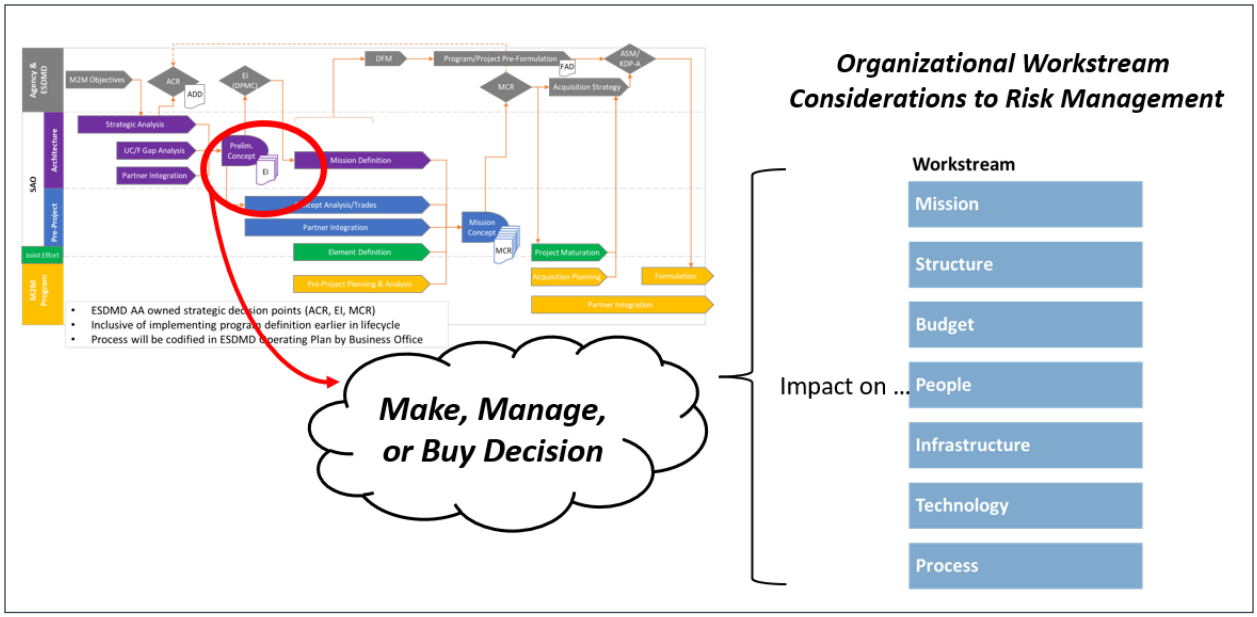


Figure C. Intersection of ESDMD Technical Milestones and NASA 2040 Workstreams

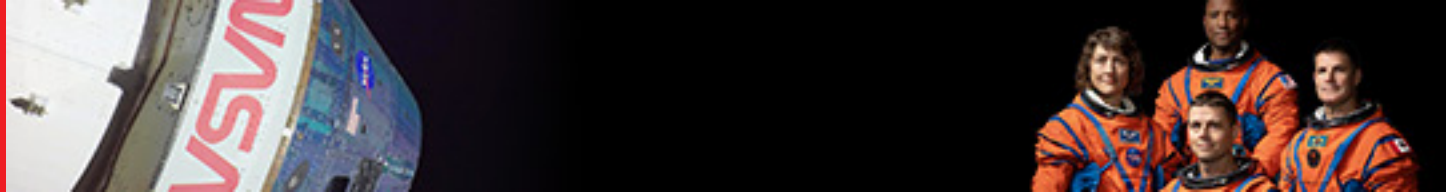
processes and discipline, and required infrastructure. With the momentum and progress that NASA has achieved to date on this recommendation, and the current vector it is on, the Panel is excited to see the full operationalization of the strategy next year.

B. Agency Governance

Over the last three years, the Panel has made a series of observations and refined its focus and recommendation on Agency governance. The Panel's emphasis on governance has principally focused on how NASA HQ engages the leadership team, including at the Centers and in the programs, sets and communicates strategy, and then holds leaders at all levels accountable to execute accordingly. Specifically, the ASAP sees a direct connection between how deliberately NASA aligns its leaders and workforce to Agency strategy and priorities, and how effectively risks are then managed in the difficult, unforgiving, and increasingly complex human spaceflight portfolio.

The Panel observed in 2020 that the Agency's program management and procurement formulations had shifted over the decades since Apollo, necessitating a revised management approach. Specifically, the Panel suggested that NASA: (1) explicitly consider the risk and benefit to each partnership, (2) transparently communicate expectations consistent with each partnership, and (3) establish deliberate management practices that reflect and deliver on those expectations.

Panel discussion with NASA in 2021 focused more narrowly on deliberate transparency, engagement, and alignment. This led to a formal recommendation focused on governance to establish an Agency "board of directors" approach to senior leadership.



Recommendation 2021-05-02: As a part of an overall risk management approach and 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.

In 2022, the ASAP explained this recommendation further, clarifying that the Panel's central concern is how senior leaders engage, align to agency-level priorities, and then are held accountable to execute accordingly, not that the Agency should establish a separate governing body as the recommendation title inadvertently implied. As part of an overall risk management approach and to deliberately facilitate behaviors that combat organizational silence and enhance management effectiveness, the Panel recommended NASA engage its senior leaders, including Center Directors and other key officials, in a governance culture that emphasizes accountability to the Agency's mission as a cohesive whole. The inherent goal being to improve alignment toward holistic Agency objectives and strategies, rather than toward individual Centers or components of the Agency in isolation.

It is clear in 2023 that NASA has made remarkable strides in deliberate alignment and strategic decision making as evidenced by the Agency's progress coalescing a M2M campaign vision and strengthening the Artemis program structure, integration, and leadership. The Panel sees this progress as an enabling sea-change and directly applicable to the governance recommendation. As evidenced by the Artemis ACR that NASA uses to integrate agency-wide program strategy, the *NASA 2040* vision the Agency is developing to optimize infrastructure and workforce, and the Agency's use of existing management forums like their Federated Board to review strategies and make recommendations, it is clear that NASA is taking intentional steps to deliberately use full and open forums to maximize transparency and engagement, articulate and adjudicate agency-level priorities and strategy, and deliberately align to Agency goals.

The final step the Panel recommends in governance is about accountability. As noted in the *2022 Annual Report*, the Panel recommended NASA "expect Centers to then execute accordingly, bringing exceptions, new information, reclamas, et. al." back to the board, (i.e., the senior leadership team as a group). Inherent in this are both the *expectation* to execute accordingly and being held *accountable* to do so, from budget submissions to infrastructure and workforce decisions. This orients the Agency at all levels to the governing strategy and core missions and will, in turn, strengthen mission success, cost performance, efficient resource allocation, and deliberate integrated risk management. As *NASA 2040* generates actionable plans to operationalize its strategy and establish performance expectations, this governance approach should create appropriate agency-wide accountability. The ASAP therefore considers this accountability to be an important element and

remains interested in better understanding how Center Directors and PMs are held accountable to achieve Agency objectives across a full spectrum of risks.

C. Moon to Mars Program Management

In the *ASAP Annual Report for 2021*, the following were areas of concern regarding program management across the NASA enterprise:

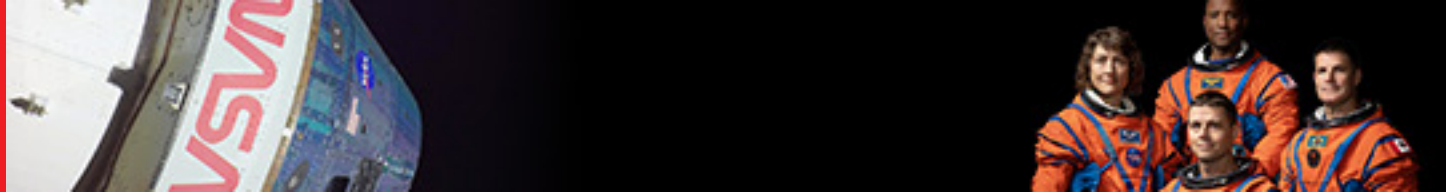
- There is no top-level Artemis program, and therefore no Artemis PM, to provide comprehensive and aligned integrated guidance that directs resources of all Artemis programs and projects in a cohesive manner to manage the overall risk.
- There is no Artemis campaign prime integrating contractor, nor clarity on how important risk management functions are being accomplished in its absence.
- An unprecedented mix of acquisition approaches with asynchronous delivery time horizons presents risk management challenges.
- Regardless of whether a partner-approach or an acquisition-approach is used, consistent expectations of transparency and data-driven discussions are required.

Due to the risk implications of the concerns noted above, the Panel issued the following recommendation:

Recommendation 2021-05-03: NASA should manage Artemis as an integrated program with top-down alignment, and designate a Program Manager endowed with authority, responsibility, and accountability, along with a robust bottoms-up, collaborative feedback process for both Systems Engineering and Integration (SE&I) and risk management.

NASA has made impressive strides in program management over the last year, both organizationally and technically, to address many of the Panel's concerns. NASA has established the M2M Program, and assigned a PM with requisite authority, accountability, and responsibility. Top-level processes, including program and project integration using M2M master schedules and identification of M2M program and safety risks, have matured briskly.

In addition to the creation of the M2M program office, NASA has addressed one of the Panel's greatest concerns regarding integrated risk management. At the end of 2022, NASA had assigned the development responsibilities of the Artemis campaign to ESDMD, and the operational responsibilities of the Artemis campaign to Space Operations Mission Directorate (SOMD), two separate directorates. As every Artemis mission is likely to be akin to a test flight, it was difficult for the Panel to understand how integrated risks would be handled effectively – that is, how it would be clear who had responsibility and who would be held accountable to accept those risks. This issue of organizational dissonance has now been resolved. Instead of



dividing the management of integrated Artemis risks between two major NASA directorates, each with its own risk processes, the M2M PM now has all the integrated risk management responsibility under a single hierarchy and importantly, has established traditional program management risk processes that are familiar to the workforce.

In 2023, NASA also completed a major review for improved architecture-to-design management. Two years ago, when the Panel issued this recommendation, there was no clear architecture that could identify top level requirements or clarify system engineering and integration challenges and opportunities. Since that time, the NASA team has established a baseline architecture and established an agency-wide Architecture Review Process to update the architecture in a disciplined systems engineering manner as the Artemis campaign unfolds. The outcomes of this review process clarify top M2M-level objectives for the campaign, establish the long-term roadmap of how elements of the architecture fit together and drive top level requirements, reveal system engineering and integration challenges and risks, justify key science and technology investments, and frame the assessment of operational needs. Most importantly, the architecture efforts have established the "Why" behind the campaign and better define the trade space for Artemis integrated engineering plans. It is a process that can be considered a "Whole-of-NASA" effort that engages all stakeholders and has the attributes of a governance system the Panel sees as critical to overall integrated risk management for a program as widely impactful as the Artemis campaign. In the Panel's assessment, this has been a groundbreaking effort that will be key to NASA's success in returning to the Moon and beyond.

As a result of the clear and unambiguous establishment of the M2M Program, along with the substantial progress in focus and cohesion in support of risk management, the Panel recommends that this recommendation be closed. That said, some of the challenges noted in the *2021* and the *2022 Annual Reports* remain, including risk management in the absence of a prime integrating contractor, program integration across multiple acquisition approaches, and an irregular cadence — each of which will be discussed later in this report.

IV. Moon to Mars Program Assessment

A. Artemis II

2023 was an impactful year for NASA's preparation of Artemis II, the first human mission to return to lunar orbit since the Apollo era. **Figure D** depicts the operational mission plan. The current launch date of Artemis II is estimated to be no earlier than November of 2024, and the M2M program has a considerable workload of broad scope and scale with numerous critical milestones ahead of that launch date. This gives rise to important risk-related challenges.

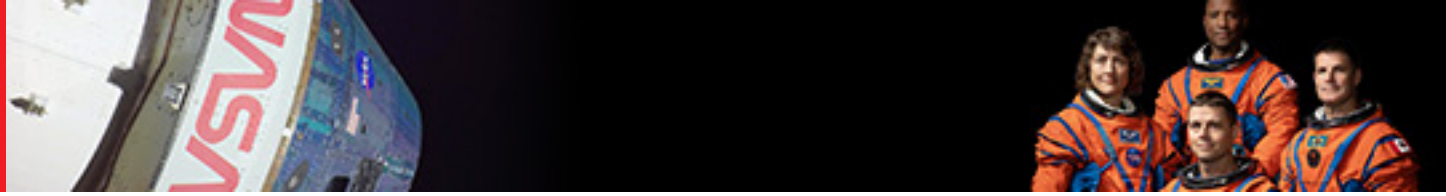
Currently, these include disposition of off-nominal issues from the flight of Artemis I, maturation of crew training programs for the newly announced Artemis II crew, maturation of Mission Control readiness for crewed flight operations, and ongoing technical issues that must be reconciled prior to key processing milestones, such as the Orion mate with its service module.

There are two key issues that the ASAP is following closely for Artemis II: the Orion heat shield performance and the Orion Side Hatch delta-pressure capability for nominal and contingency operations. The Artemis

Figure D. Artemis II Operational Mission Plan

Program Office is coming closer to finishing important testing in support of its heat shield root cause analysis effort which will inform the path forward. The program office is also conducting side hatch delta-pressure testing that should help define the system's limits and operational and contingency operations procedures. The Panel will continue to watch these notable risks to closure.

In the face of these and other challenges, the ASAP notes that the stand-up of the M2M Program Office during the middle of 2023 appears to have provided a notable advantage of organizational clarity at a critical time. In the Panel's view, leaders of the Artemis campaign are now much better positioned to address the risk management challenges of Artemis II. Integrated risk management products and processes are appropriate and maturing, and there is a newly established transparency regarding responsibilities and authorities for risk decisions. In essence, NASA has returned development programs to a classic integrated risk management model that is familiar to the overall workforce and in which they are expert. This model is deeply embedded in the Agency's culture, which means that the workforce is broadly familiar and comfortable with risk management processes, to the point that they have inherent understanding of their roles and responsibilities. NASA will, of course, need to sustain its vigilance to thwart complacency, hubris, and organizational silence. As the Artemis II processing flow and preparation proceeds through its challenges, the M2M Program structure has boosted confidence that those challenges will be comprehensively and transparently addressed and dispositioned.



B. Artemis III

The Artemis III mission plan, as depicted in **Figure E**, is of concern to the Panel, due to the aggressive launch timeline combined with the number of "firsts" that must be accomplished to achieve Artemis III objectives, many of which must be performed sequentially in a fully successful manner even before its launch. The following is a *partial* list of the "firsts" either attempted as a demonstration before the Artemis III mission or attempted on the Artemis III mission itself:

- **A.** First mission dependent on the Human Landing System (HLS) — requiring approximately 15 fueling launches to support Artemis III
- **B.** First launch of the new Orion variant
- **C.** First use of HLS LEO Depot station — including cryo refueling
- **D.** First HLS Launch from Cape Canaveral on a new launch pad
- **E.** First HLS Lander/Orion rendezvous and docking in lunar orbit
- **F.** First HLS uncrewed lunar landing
- **G.** First HLS uncrewed demonstration of a successful lunar ascent
- **H.** First HLS crewed landing on the Moon
- **I.** First Lunar Extravehicular Activity (EVA) since 1972
- **J.** First use of new EVA suits
- **K.** First HLS crewed ascent from lunar surface to lunar orbit
- **L.** First use of Lunar surface communication and broadly integrated communications system
- **M.** First landing at the challenging South Pole site

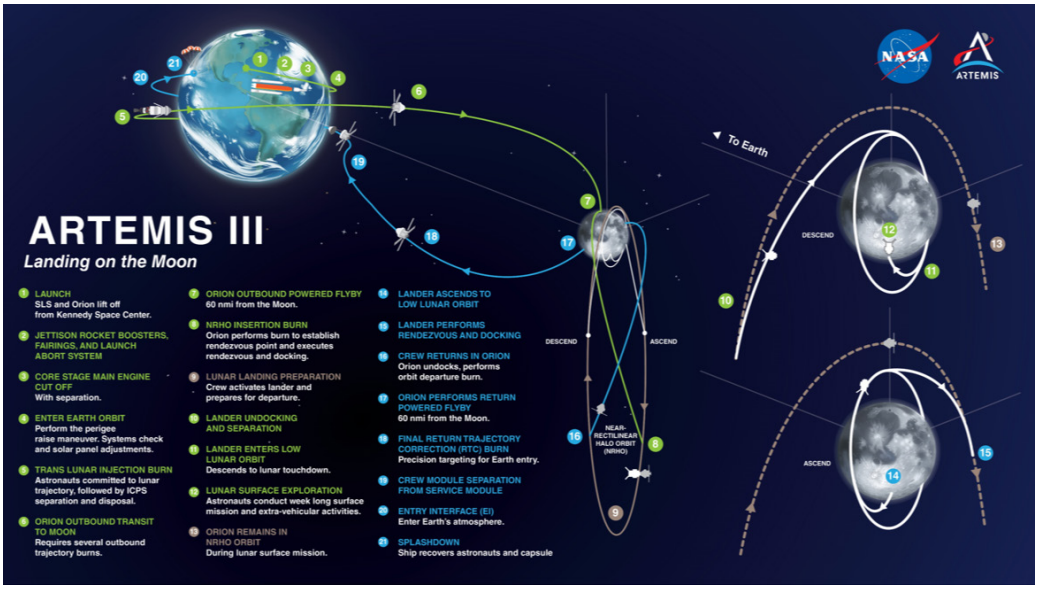


Figure E. Artemis III Operational Mission Plan

In addition, prior to the Artemis III mission, NASA will need to address whatever issues arise from the Artemis II mission, including the possibilities of hardware (HW) and software (SW) changes to both the Space Launch System (SLS) and Orion. Orion flight time on Artemis III will exceed previous durations. Given that it is a new rocket, a new human capsule, and a new human spaceflight environment for this generation of NASA workers, it is not unreasonable to think that NASA will still have a great deal of discovery to do with every Artemis mission for the foreseeable future, and that both schedules and workloads will need to expand accordingly.

With all of these and other significant technical firsts occurring during this single mission, the Panel is genuinely concerned that they represent an even greater cumulative risk to an already difficult and complex Artemis III flight. There will be extraordinary pressure for timely execution of a schedule that in many ways is beyond NASA's full control, and at a level of integrated risk that will challenge the workforce to the extreme. Therefore, the ASAP does advise NASA to consider a redistribution of Artemis mission content across the individual missions to ensure that the overall integrated risks are at a level that the NASA workforce can effectively manage without undue schedule pressure.

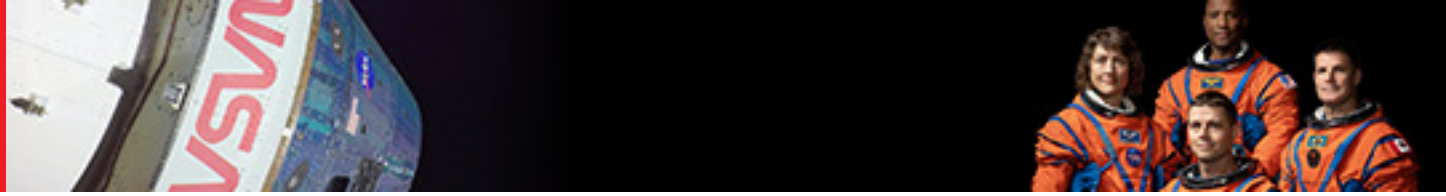
C. Artemis Campaign Ongoing Concerns

1. Risk Management in the Absence of a Prime Integrating Contractor

As historical context, NASA has effectively relied on a prime integrating contractor to manage SE&I across subprograms and projects to ensure there is a consistency of standards, practices, and developmental outcomes across the program enterprise. Generally, a prime integrator performs critical activities across the integrated program such as:

- Deriving requirements
- Performing technology assessments
- Conducting risk assessments across the integrated program
- Conducting safety hazard analysis across the integrated program
- Determining specifications
- Conducting independent verification and validation
- Directing all other contractors' operations in a coordinated manner
- Developing test requirements and evaluating test data
- Monitoring all contractor and subcontractor performance and work

For instance, although the Space Shuttle program executed multiple launches a year, it was never considered truly "operational." In truth, NASA's most highly reused spacecraft continually evolved in its HW, SW, and operational parameters throughout the life of the program. Every Space Shuttle mission presented new risks that required active integrated risk management, in which a prime integrating contractor played a key role.



However, unlike the Space Shuttle and the International Space Station (ISS) programs with their supporting prime integrating contractors, NASA has decided to forgo a prime integrator and, in essence, be the Lead Systems Integrator (LSI) for the M2M Program and Artemis Mission Campaign. This approach is more comparable to how NASA operated during the Apollo Program. The Panel believes this decision and approach can be successful; however, the Panel also believes it is important that NASA understands all the roles and responsibilities for which a prime integrator has generally been accountable and appropriately addresses those responsibilities. As the designated LSI, NASA has accepted both the responsibility to lead these efforts and the accountability for the results. NASA must therefore ensure the Artemis Program Office is properly resourced with the right personnel, workforce depth in key functional areas, and the appropriate level of funding to execute this complex and critically significant role. Strong and steady congressional support as the Agency embarks on this national priority and incredibly complex endeavor is equally important.

The M2M PM must also establish certain processes, procedures, and integration roles for the government to fulfill. Though not a comprehensive list, the following are exemplar watch items and areas of focus for NASA to consider as the LSI:

- Align the critical activities noted above between the different NASA Centers, Artemis program elements, and contractors to retain a consistent risk management approach that eliminates inconsistencies, opaqueness, and dissonance.
- Maintain a strong and disciplined systems engineering workforce, infused with a pipeline of a new generation of NASA engineers.
- Ensure disciplined engineering processes based on first order principles are in place.
- Use the architecture to anticipate future workforce needs and technical competencies.
- Actively manage interfaces across all elements of the architecture.
- Ensure NASA and its contractors understand their roles and responsibilities, especially with respect to safety and risk resolution.

From the discussions that the ASAP has had with the ESDMD leadership team, Artemis PM, and the relatively newly established Program Office team, the Panel believes that NASA understands the role they have undertaken and are proceeding in a disciplined manner. In the past, NASA has internally performed these tasks and certainly has retained some necessary core competencies to accomplish the LSI role. The Panel would like to learn more in the coming year about how NASA's current approach, which involves a disparate collection of integrating contractors across multiple NASA Centers, programs, and projects, attains the same historic level of integration and results for successful risk management without duplication of effort or even conflicting outcomes. The ASAP will continue to watch this area given its criticality to the success of the Artemis Campaign and its direct implications for safety and technical program risk.

2. Program integration Across Multiple Acquisition Approaches

Earlier in the report, the Panel discussed the sound initiatives that NASA has undertaken in the acquisition process to understand integrated risk across the overall Artemis campaign well before the acquisition strategy

is finalized and program execution begins. The Panel applauds these efforts and believes it will be extremely beneficial to comprehend risk implications before any new elements are added to the overall architecture, such as the Lunar Rover, Lunar logistical support equipment, and even the ISS deorbit vehicle, all of which will compete for Agency resources.

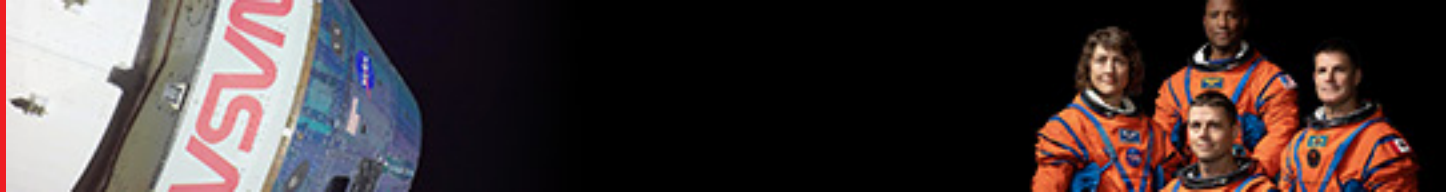
Even with more rigorous acquisition processes now in place, there are many critical elements of the overall M2M program with predetermined acquisition strategies already in the midst of execution (such as Gateway, HLS, and international partner contributions like the European Service Module). Most of these decisions and risks related to element acquisition approaches have been made for the earlier Artemis missions prior to the stand-up of the M2M Program Office and were initiated without the benefit of a detailed integrated architecture, integrated program schedule, or a well-defined concept of operations driven by a single senior PM.

Since these acquisition strategies are in execution, the Program Office must be attentive to the challenges and risks they pose as it surveils the campaign. Scanning the portfolio of projects that compose the Artemis campaign architecture, it remains unclear to the Panel how and when individual elements of the Artemis mission sets cohere given the diverse and asynchronous contracting approaches and timelines. These tightly coupled programmatic efforts must be actively reviewed to discover inherent disconnects that impact safety and manifest integrated risks. Based on its discussions with the Agency, the Panel is confident Agency leaders at all levels understand this challenge and is encouraged by the new PM's focus and the actions he and his team have initiated to address this concern both programmatically and technically. The ASAP looks forward to further examination of this challenge in the coming year.

3. An Irregular Cadence

The planned cadence of the Artemis campaign is not conducive to creating an experienced workforce proficient at complex launch flows. The break between launches for Artemis I and Artemis II is projected to be two years, and as noted earlier, the program development content currently necessary to execute Artemis III presents even greater challenges when it comes to meeting the current Artemis Campaign schedules. Given the complexity and cost of each individual mission, the ASAP expects there could be significant time delays of some unspecified duration between Artemis launches. In the Panel's view, a low and/or irregular launch cadence can induce unintended consequences that directly undermine safety, such as undue schedule pressure and oversubscribed missions. Now that the Agency has a well-defined set of M2M objectives, the ASAP encourages NASA to factor the consequences of a low launch cadence into its overall risk calculus to achieve desired outcomes and to consider how those risks might be rebalanced.

Given NASA's expected level of congressional support, at least one Artemis launch per year offers the NASA community their best opportunity to learn, train, develop, and adapt to future discoveries and evolving requirements of the overall campaign – as every mission builds upon the missions that came before. A regular launch cadence offers the operational teams their best chance to focus on preparation, readiness, process improvements, and risk management, instead of grappling with uncertainty in an ever-evolving situation. Even at the optimum cadence, however, NASA will be challenged to form and retain a highly experienced operational team. To its credit, NASA is already taking steps to manage the expected turnover and loss of



corporate knowledge in the workforce due to the gap between the first two launches. The Panel will further investigate NASA's approach to workforce management and launch cadence in the coming year.

4. Integration of the Operational Perspective

The ASAP not only holds discussions with NASA program and technical personnel, but also with critical members of the operational workforce, to include astronauts, flight directors, safety advisors, and other members who carry responsibilities for mission execution. In the Panel's view, embracing the operational perspective throughout the development process continues to be essential to any program with a strong, positive safety culture. Engaging the operators early in development and design processes has been a critical component of past successes and will serve NASA well in the Artemis era. Under the leadership of the M2M PM and ESDMD, there is a wealth of opportunity to leverage operational perspectives, with the goal of improved safety and mission assurance, to include ACR/MCR milestones, architecture forums, M2M Board/panel representation, program/project SE&I processes, and other risk-related decision points. The ASAP also encourages continued operator engagement for mission concept of operations design, including the core operational precepts of appropriate vehicle command and control, comprehensive navigation, and robust communication, to identify early the operational risks and challenges for each and every mission.

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

Previous sections of this report have highlighted that NASA is generally meeting the challenge of managing the complex system of systems and missions that comprise the lunar campaign. While the Agency has a firm focus and structure around its future endeavors in cislunar space, NASA is not planning to abandon operations in LEO, where the vision for future operations is quite exciting. More than 3,000 scientific experiments have been conducted aboard the ISS in the 23 years since it has been continually occupied. This scientific research and the observation of crew health in long duration microgravity have contributed significantly to the buy-down of risk for continued and more ambitious human exploration of space.

NASA is taking advantage of, and acting as a facilitator for, increasing engagement by private enterprise in space activities. The Agency is planning to transition from an owner/operator of an orbiting LEO space lab, the ISS, to being a customer (ideally, one of many) for industry-led LEO-based space stations. The shift parallels and is a progression of the industry-led approach that the Agency took, first for cargo deliveries to the ISS, and later for crew. Retiring the ISS, which at its end-of-life (EOL) will have been in orbit for approximately 30 years and considerably beyond its original anticipated life, provides an opportunity for NASA to apply the "commercialization" of services paradigm to orbiting laboratory services.

NASA's commercial cargo and crew programs have offered many lessons for the Agency and the broader industry about how to understand and manage risk, define accountability between government and industry, and fine-tune certification processes to ensure safe operations. New insights continue to emerge as vehicle designs evolve and operations mature. As industry progresses toward development of a private orbiting laboratory capability, the Panel is monitoring several important topics that will directly affect how risk is identified and managed.

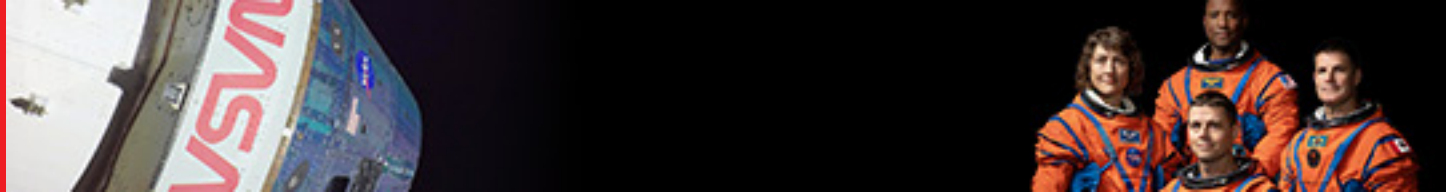
A. Transition to Commercial Low-Earth Orbit Destinations

In October 2023, NASA briefed the ASAP on their LEO transition planning that included LEO's goals, objectives, and recurring tenets as listed in **Figure F** below.

Figure F. LEO Goals, Objectives, and Recurring Tenets

NASA's intent to sustain a human presence in LEO depends on a successful transition strategy from ISS operations to some participation on commercial low-Earth orbit destinations (CLDs).

NASA's current plan for ISS transition relies on the CLD industry with timelines that may be unrealistic. As one example, while Axiom Space's design for its commercial destination for ISS (CDISS) is planned to be in orbit by the end of 2026 with minimal research capability, it may not reach full capability prior to ISS early EOL and would need to be able to operate independently. Therefore, as part of the development,



NASA is working with Axiom, **Figure G**, to ensure that they can depart from ISS prior to reaching their full capability and finish their development independently should ISS reach early EOL. Other possible CLD options such as **Figure H** and **Figure I** remain strongly influenced by market forces. The Panel, watchful of these dynamics, remains concerned that there is not a fully integrated program schedule, with a clearly defined critical path timeline, to enable a seamless transition from ISS operations to another platform with acceptable safety risk. To facilitate a timely, safe transition, NASA needs to fully develop its LEO goals and objectives as clearly articulated and detailed objectives for their sustained human presence in LEO.

Figure G. Axiom artist's concept of planned commercial space station.

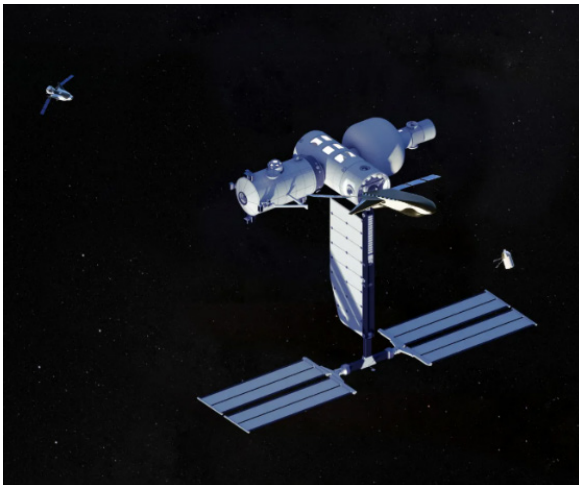


Figure H. The Blue Origin and Sierra Space Orbital Reef baseline configuration.

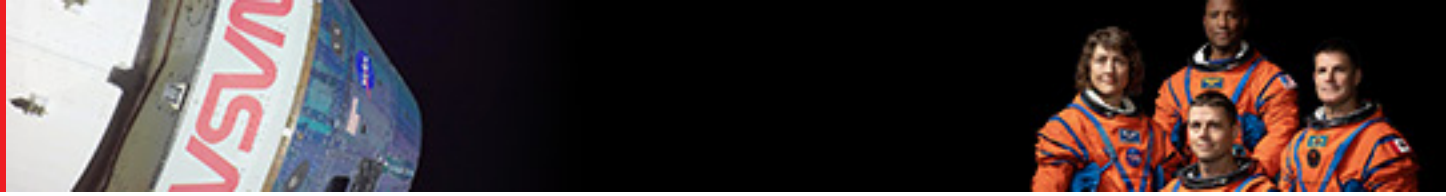
Figure I. Starlab, from Nanoracks, Voyager Space, and Airbus.

Managing and understanding integrated risk across the complex transition from ISS to a CLD is challenging and requires a clear rationale, a viable execution plan, and a supporting budget. This plan should not only outline the transition of LEO objectives to alternative LEO platforms, but should also identify NASA's expected roles, responsibilities, and authorities as the Agency operates on a space station it neither owns nor maintains. To best prepare to manage the risks of the transition to come, NASA should outline requirements for a workforce tailored to accomplish independent CLD operations, develop a plan to disposition valuable contents of the ISS, and establish a funded deorbit plan.

The ASAP believes NASA should adopt as concerted an approach here as it did with development of the objectives for the Artemis campaign, to include clarity on the driving requirements for continuing LEO operations. In the *2021* and *2022 Annual Reports*, the Panel noted a series of challenges with the Artemis campaign, including the need for comprehensive and aligned integrated guidance and supporting architecture that directs resources and projects in a cohesive manner to manage the overall risk. These challenges include the need for clarity on how important risk management functions are being accomplished, clear governance of an unprecedented mix of acquisition approaches with asynchronous delivery time horizons, and consistent expectations of transparency and data-driven risk discussions. These same challenges are pertinent to the transition to CLDs. As emphasized in the *2022 Annual Report*, to affect a safe transition from ISS to CLDs, the Panel believes NASA's activities in LEO can benefit from a similar strategic approach to that employed for Artemis, including articulating architecture, requirements, SE&I, and integrated schedule and program management. Equally important, NASA should explicitly define the objectives for spending Agency resources on CLDs and for putting NASA astronauts in a risky environment without most of the direct insight and control exercised in NASA-executed spaceflight.

In the *2022 Annual Report*, the Panel noted that the transition to a commercially owned and operated destination raises many fundamental strategic, technical, and operational questions, many of which are not answerable by NASA alone. As NASA's LEO transition plans have evolved, the ASAP notes that the following questions are still relevant concerns:

- Will there be a consistent US Government position on NASA's role in LEO operations?
- How much is the US Government willing to invest in the CLD market to ensure an orderly LEO transition?
- 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, what is the overarching integrated architecture to support safe and effective operations?
- 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 ISS reaches its planned EOL in 2028 or 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?
- Given the public safety risks related to an uncontrolled ISS deorbit, what is the strategy to manage a controlled ISS deorbit at EOL, and in the event of a major contingency?
- What scientific research needs to be conducted in microgravity to help ensure the safety of current and future space exploration crews?
- Overall, for each of NASA's LEO goals, objectives, and recurring tenets, and following the questions listed here, what is NASA's "Why" for LEO – what is the Agency's mission-related need that is addressed?

Considering the strategic challenges and questions of LEO transition, the Panel makes the following recommendation:

Recommendation 2023-04-01: 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 ASAP believes NASA should adopt as concerted an approach here as it did with development of the objectives for the Artemis campaign, to include clarity on the driving requirements for continuing LEO operations.

B. International Space Station

The ISS program continues its record of success, despite a complex flight plan, high operational tempo, and various uncertainties, ongoing concerns, and emerging technical challenges. The program continues to maintain excellent and cooperative relationships with international partners in the face of global geo-political tensions. The primary concern involving the ISS is that it continues to age and will eventually need to be removed from orbit and disposed of in a controlled manner; this need to deorbit safely is not completely in the Agency's hands. Aging HW is a contributor to the multiple microscopic cracks which have been detected in one of the ISS modules and have resulted in leakage of air over the last few years. While the aging HW points to the steadily approaching end of the Station's life and the need for planning a controlled deorbit, it must also be noted that a critical or catastrophic failure could occur with little or no warning, necessitating an

immediate safe disposal of the damaged station. The risk of incipient failures is highlighted by the occurrence of multiple coolant leaks, believed to have been caused by micrometeoroid or orbital debris (MMOD) impacts on ISS HW and visiting vehicle.

To allow for sufficient time to transition LEO science and technology development from the ISS to subsequent new US commercial orbiting laboratories, NASA and most international partners have confirmed that they will continue to support ISS operations through 2030. The Panel is particularly concerned about the ISS deorbit plan, a critical need with explicit safety implications.

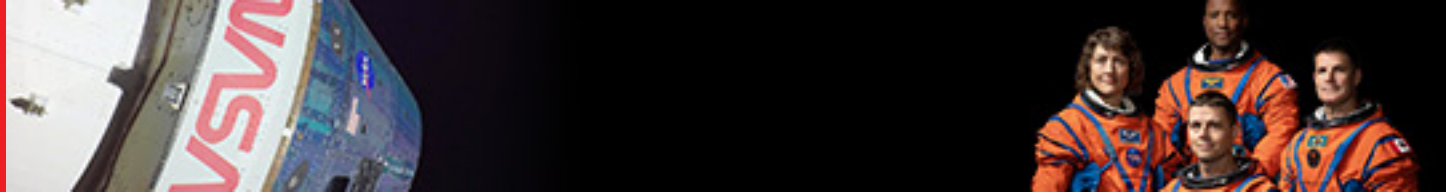
Over a decade ago, the Panel made a previous recommendation pertaining to ISS deorbit capability:

Recommendation 2012-01-02: (1) To assess the urgency of this issue, NASA should develop an estimate of the risk to ground personnel in the event of uncontrolled ISS reentry. (2) NASA should then develop a timeline for development of a controlled reentry capability that can safely deorbit the ISS in the event of foreseeable anomalies.

The ASAP closed this recommendation in 2020 because, at the time, there was complete conceptual agreement on an approach across all the partners, and a final agreement was described as imminent. Subsequent detailed discussions among the ISS partners identified technical and operational issues that needed further attention. The urgency of defining a deorbit plan, first highlighted in 2012, is now even more pressing given the steadily approaching end-of-life date. In last year's Annual Report, the Panel returned to this topic and reiterated its concern 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. Absent finalized contingency plans and capability to deal with an emergency deorbit situation or a possible impasse between ISS partners on how to execute the deorbit plan, the ISS partners are operating at risk today. The risk to public safety and space sustainability is steadily growing as the orbital altitudes at which the ISS operates continue to become more densely populated by satellites, increasing the likelihood that an unplanned emergency ISS deorbit would also impact other resident space objects. Earlier studies on the risk posture and safety implications of an unplanned deorbit likely require regular reviews given the rapidly changing nature of LEO activities.

Because of continued concerns, the Panel issued the following new recommendation in its *2022 Annual Report*:

Recommendation 2022-05-01: 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 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.



Considering escalating risks and a clear need for a deorbit capability, NASA released late in 2023 a request for proposal (RFP) to develop a US Deorbit Vehicle (USDV), with a contract award expected in early 2024. On December 5, 2023, NASA issued a revised RFP for the USDV with a new submission deadline of February 12, 2024. Other updates to the RFP include desired delivery and launch dates, and requirements for bidders to lay out various cost development options. When issuing the revised RFP, NASA acknowledged that the USDV will take years to develop, test, and certify. The ISS deorbit timeline outlined above leaves only five years for successful development and launch of the USDV. While this timeline is challenging enough, a more serious challenge at this point is how the USDV will be fully funded. Given the uncertainty over both funding and the feasibility of the USDV development schedule, the Panel now re-emphasizes last year's recommendation, namely: a controlled deorbit capability must be developed for the ISS as soon as practicable. NASA must also address a plan for deorbit in the event of a major contingency and how safe disposal of the ISS could be accomplished before the USDV is available. The ASAP is aware that an interim capability, while urgently necessary, may represent a much higher risk solution with more uncertain outcomes and thus could be unsuitable for a planned EOL ISS disposal. The ASAP notes, however, that an uncontrolled reentry of the ISS is the riskiest outcome of all, especially to the worldwide public.

C. Commercial Crew Program

Since the inception of NASA's Commercial Crew Program (CCP), the Panel has closely followed the program's progress, as well as its awareness and management of safety risk. During 2023, as in previous years, the ASAP has paid particular attention to specific safety and technical challenges facing both CCP providers and to the program's status with respect to meeting the essential goal of providing assured, ongoing access to LEO.

As for issues involving SpaceX, NASA is working with the ISS Program and SpaceX to modify Space Launch Complex 40 (SLC-40) at the Cape Canaveral Space Force Station in Florida. While Launch Complex 39A (LC-39A) at the Kennedy Space Center is still the primary CCP launch site for SpaceX, **Figure J**, completing

Figure J. A SpaceX Falcon 9 rocket carrying the company's Dragon spacecraft is launched on NASA's SpaceX Crew-7 mission to the International Space on August 26, 2023, at NASA's Kennedy Space Center in Florida.

modifications and certification of SLC-40 will make it available as an additional site, helping to mitigate potential schedule risks for crew and cargo launches.

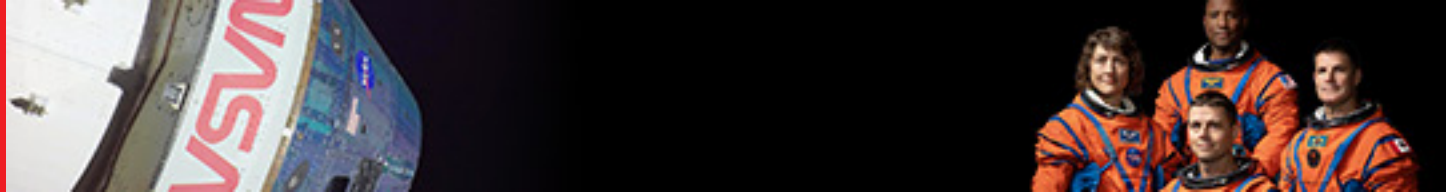
In addition to modifications at SLC-40, SpaceX has been working to prevent and mitigate valve corrosion on reused Dragon capsules. In general, the Panel cautions NASA to be aware of the significantly high pace of operations with SpaceX, and to track fleet-wide issues for applicable risks.

Boeing, **Figure K**, is addressing several technical issues in preparation for the Crewed Flight Test (CFT) of its Starliner spacecraft, currently planned for no earlier than mid-April of 2024. The issues with Starliner currently being worked are summarized below.

- Efforts have been made to mitigate risk posed by the presence of P-213LW tape in the Starliner crew compartment. When all accessible P-213LW tape has been remediated, an assessment will be necessary to ensure that the risk from any remaining tape is acceptable.
- A critical drop test of Starliner's upgraded drogue and main parachutes will be necessary. The new parachutes will feature strengthened main canopy suspension lines and redesigned soft link joints, increasing the safety factor of the system.
- NASA and Boeing are working through the long-term Starliner battery redesign plan. Battery mitigations will go through the board approval process when ready.
- It was recently identified that strengthening of the landing airbag backing panel is necessary to increase operational flexibility on returns and allow for landing in higher winds.

Boeing is addressing these issues and clearly maintains the position that they will not launch CFT until all risks are mitigated to acceptable levels. The Panel will monitor progress made in closing these issues, as well as new challenges, if any, that could threaten the ability to launch CFT on schedule.

Figure K. The Starliner team works to finalize the mate of the crew module and new service module for NASA's Boeing Crewed Flight Test at Kennedy Space Center in Florida on January 19, 2023.



The CCP's original intent was to have two providers for redundancy and greater resilience. That is, if any mishap or major setback occurred with either provider, the overall program would continue, with a greater chance of assured access to LEO via the other provider. Through the lens of hindsight, it could be said that the original intent has paid off, as NASA achieved and has maintained access to LEO. Today, however, the situation looks different than it did when CCP was conceived. One provider, SpaceX, has settled into a regular cadence of successful launches, crew transfers, and landings. On the other hand, the other provider, Boeing, continues working to overcome technical challenges that must be resolved before they can proceed to their first crewed launch. While NASA would still realize benefit from having a reliable second provider, the various factors discussed in this section should form the framework of a continued risk-benefit analysis to ensure the overall risks remain acceptable.

VI. Area of Emerging Focus: Health and Medical Risks in Human Space Exploration

Health and medical risks in human space flight contribute directly to the overall mission risk profile and are an integral part of overall safety. At the highest levels, health risks are generally due to untoward exposure factors that may be incurred through all mission phases. Broad examples of such factors include toxic substances, microgravity, space radiation, and isolation and confinement. Acceptable levels of exposure are defined by NASA health standards, which are nationally vetted, specific to exposure factors, and integral to human space flight program management and execution. NASA manages these standards and their expression in human space flight programs through the Health and Medical Technical Authority.

Medical risks generally involve the likelihood of crewmember illness and injury during missions. NASA has historically addressed medical risks at the highest level through space flight crew medical selection and flight qualification standards. Medical waivers based on a solid, evidence-based space medical rationale are considered and may be granted for crewmembers for flight qualification; medical waivers are not considered for selection. NASA also addresses medical risks through the deployment of medical treatment capability on-board human spacecraft, and through the practice of space medicine during the mission. NASA further mitigates these risks in LEO operations by the ability to evacuate crewmembers to more robust and definitive ground-based care within 24–36 hours of illness or injury onset. NASA health and medical authorities also use Probabilistic Risk Assessment based medical modeling to assess likelihood of medical events. The probability estimates allow comparison of medical risks to other risks across the programmatic spectrum and can help guide medical resource allocation.

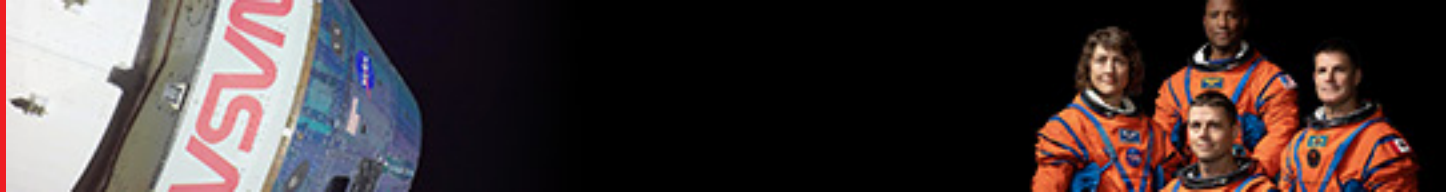
NASA, along with its international partners, is the custodian of the world's most complete and comprehensive human space flight health-related standards and has the bulk of the world's experience in dealing with human health maintenance, illness, and injury in flight. NASA medical authorities are actively sharing space flight medical selection standards and medical experience with the commercial space flight sector, other domestic agencies such as the Department of Defense (DoD) and the Federal Aviation Administration (FAA), and new potential international partners. This includes search and rescue operations, prepositioning medical assets to respond to launch and reentry mishaps, and mishap investigation experience. NASA and its international

partners have been remarkably successful in both preventing and treating illness and injury in orbit, keeping mission impact due to health and medical events to an absolute minimum. Analog experience from Antarctica and other extreme environments indicated that several medical evacuations would likely be necessary over the life of the ISS Program. To date, there have been no medical evacuations from the ISS.

The Panel commends NASA for the effectiveness of its health and medical system in LEO operations. The Panel recognizes, however, that timely evacuation to definitive ground-based care will not be available in lunar operations. Further, evacuation will be impossible during Mars missions. Power, up-mass, and volume limitations will limit NASA's ability to deploy crew health and medical systems to address inflight illness and injury. Some exposure factors, notably space radiation, isolation, and confinement, will be quite different from exposures and resultant risks in LEO. As NASA's Chief Health and Medical Officer has explained to the ASAP, life/limb risk mitigation will become subordinate to mission risk mitigation in lunar missions to Mars. This may lead to exceedingly complex decisions on the part of mission commanders in the event of serious crew injury or illness. In a Mars mission scenario, mission commanders might have to make such life/limb decisions in the context of significant communication delays, with only limited resources on board to support the entirety of the mission, and without the benefit of timely consultation with ground support personnel.

The Panel would like to engage NASA's health and medical authorities in further discussions about overall health and medical risks as a contributor to overall mission risk and mission safety. Examples of high-level questions the Panel would like to explore include:

- Will NASA health standards need to be updated/revised for Lunar and Mars missions?
- Will NASA crew selection and qualification standards need to be updated/revised for Lunar and Mars missions?
- What countermeasures to radiation, microgravity, and isolation/confinement will be available on moon and Mars missions?
- What medical treatment capabilities can be provided during moon and Mars missions, and how effective or limited are these capabilities expected to be?
- How will NASA prepare for the transition to a paradigm where life/limb risk mitigation might be subordinate to overall mission risk mitigation? How will NASA prepare mission commanders for decision-making in those scenarios?
- What can still be learned from LEO operations, as a research environment and possible analogue for long duration deep space flight missions?
- How does NASA intend to address unknowns that will be encountered, especially in Mars missions? For example, the first crew that transits to Mars will face an unprecedented level of isolation and confinement that no human has ever experienced and that is extremely difficult, if not impossible, to simulate in terrestrial, LEO, or even lunar analog environments.



The Panel appreciates its interaction with NASA health and medical authorities and looks forward to learning more about the extraordinarily complex challenges attending human health and medical related risks as the Agency moves to lunar operations and on to Mars.

VII. Congressional Focus Area

In 2020, recognizing that MMOD posed a major safety issue not only for NASA, but for the entire international space community, the ASAP recommended that Congress designate a lead federal agency for Civil Space Traffic Management and provide that agency with both the authority and the resources to do the job. The Panel also recommended actions that NASA should take to support such a lead agency. NASA has taken those steps, and that part of the recommendation was closed in 2022. Congress has moved in the advised direction by identifying an office in the Department of Commerce and providing some initial resources, but, as of this report, formal authority has not yet been provided in legislation. The ASAP is hopeful that the appropriate legislation will be enacted soon but will not be satisfied until this step is taken.

At the same time, there is no designated lead federal agency for regulating commercial space activities. Some responsibilities are specified but allocated to several different organizations. The FAA is responsible for licensing commercial launches and reentries. The Federal Communications Commission (FCC) is responsible for licensing radio broadcasts from space. The National Oceanic and Atmospheric Administration (NOAA) is responsible for licensing remote sensing operations, such as taking pictures of Earth. The DoD and NASA are key players in space, but they are not regulatory agencies and hence do not satisfy that requirement.

Historically, this division of regulatory responsibilities has not been a significant concern because commercial space activities have generally been de-coupled from one another. Given the current evolution in non-traditional commercial space operations, however, including satellite servicing, space tourism, and the potential for commercial space stations, a new regulatory paradigm is necessary to manage commercial human and robotic activities in space. There is a definitive need for a designated federal agency to define and coordinate requisite regulations to facilitate the safety of non-government human and telerobotic activities and to provide a framework for how commercial entities should arrange safety relationships with government partners.

Developing rational regulatory frameworks requires a thoughtful, and usually lengthy, process. Given that it is likely to take several years to produce sound and judicious regulations for the space community, the time to begin this process is now. NASA clearly can provide expertise based on its many years of human and robotic space flight experience, but it is not a regulatory agency. The Panel strongly urges that Congress clearly designate responsibility for the regulation for safe commercial space activities.

An additional concern that demands attention from Congress is the consequential relationship between safety and solid acquisition practices. Given this, along with the complexity and diversity of acquisition approaches NASA is and will be bringing to bear, the Panel believes that robust acquisition experience is critical at all levels of NASA's leadership. The ASAP applauds the steps the Agency is already undertaking to emphasize and strengthen program management and acquisition skills among its workforce. Even so, the Panel continues to believe that akin to other government agencies that manage complex acquisitions,

NASA requires a Chief Acquisition Officer (CAO) with substantive acquisition experience. To that end, the ASAP resolutely urges Congress to require acquisition experience for the Senate-confirmed appointee who will serve as NASA's CAO.

One concluding area of concern that the Panel seeks to emphasize to both NASA and Congress is the continuing challenge and risk of budget constraints and uncertainty. Obviously, NASA does not execute its mission in a vacuum. It operates in an environment that is composed of geopolitical and fiscal realities. While the Agency is arguably undertaking its most ambitious program of work ever, it is also doing so with some challenges and without some advantages it enjoyed earlier in its history.

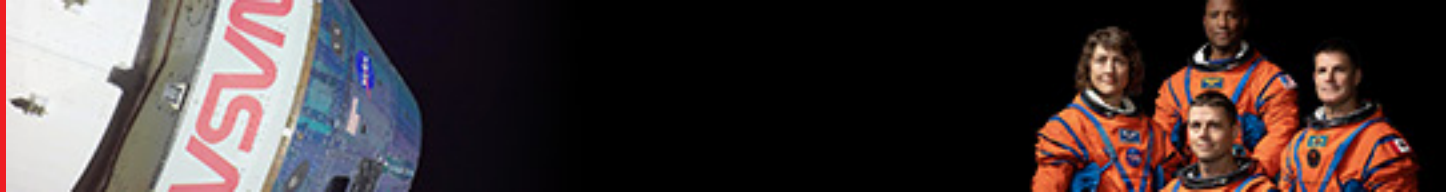
NASA, while still a leader in space endeavors, no longer exercises this leadership as a sole provider. Commercial and international providers have an increasing presence on the playing field. NASA is also no longer operating with a "clean sheet" approach but dealing with the legacy of past Executive and Legislative decisions. The Panel notes that this legacy does not, however, temper the high expectations placed on NASA's ability to accomplish its overall mission.

Moreover, NASA no longer enjoys bountiful fiscal resources. In the Apollo era, NASA was supported by substantive financial allocations made possible in an environment where the discretionary expenses were almost forty percent of the national budget. This is no longer the case and has not been for decades.

The current budget environment has significant implications for mission and safety risk. NASA has a very full mission plate. To the extent that their budget request is not fully funded, the leadership will need to acknowledge and make critical decisions with respect to program content or schedules, which will need to be adjusted to meet fiscal realities. Attempting to do all planned efforts on expected timelines will introduce unacceptable and unmanaged risk. The Agency will need to rely on its developed strategic vision, objectives, and architecture to establish well-defined priorities to ground its endeavors in reality – taking fully into account the risk-benefit tradeoffs.

It is equally critical that the Agency be transparent about these realities and choices with its stakeholder and workforce. Stakeholders must come to understand and respect realistic expectations and schedules, and the Agency cannot bow to external pressure to exceed rational anticipations. The workforce must be confident that NASA leadership's expectations are reasonable and authentic. The Agency is blessed with a workforce that has traditionally given one hundred percent to achieving difficult goals. If those talented and dedicated personnel are cognizant that they are embarked on a journey that is not just challenging and risky, but not realistically achievable, there will be both a serious erosion of morale and an undermining of the essential safety culture.

On the assumption that NASA will make the tough choices to execute safely and effectively within budgeted resources, an even greater challenge resides in the budget uncertainty resulting from Congress' consistent inability to provide timely and definitive appropriations. The ambiguity within which NASA must plan and execute its mission is deeply troublesome. It causes distraction from the focus on the "real work," including safety, adds untold hours and days of unproductive labor, and (perhaps most important) hampers the ability to make timely decisions that ultimately impact safety and mission assurance.



Given that it is unlikely that Congress will provide appropriate and timely budget clarity, NASA will be compelled to deal with this ambiguity. NASA should be candid and clear about – and Congress and other stakeholders should open their eyes to – the consequences of dealing with budget uncertainty.

VIII. Conclusions and 2024 Focus Areas

As the Panel has emphasized throughout this report, 2023 has been a highly impactful year for NASA, as notable strides have been made toward meeting a myriad of challenges during a time of mission evolution. Not only has NASA successfully flown the first Artemis mission, but with the standup of the M2M Program Office, the Agency has removed organizational impediments noted in the Panel's previous reports and is quickly maturing its integrated risk management strategies. The architecture work that led to the M2M objectives was not only deeply rigorous but also engaged all of NASA's leadership team to contribute to its genesis and implementation. The challenges of maintaining an aging ISS in the face of geopolitical realities and a new commercial transport strategy has shown NASA at its best and strongest. The Panel's view is that NASA has been particularly adept this past year at working not only the "nuts and bolts" of essential human spaceflight development and operations, but also at reinvigorating a strategic vision that will place the Agency on course for a more comprehensive integrated risk management approach in an increasingly complex environment.

Looking forward to 2024, the Panel will keep focus on progress toward meeting the current open recommendations, both with NASA and with Congress. In addition, the Panel will delve further into the state of NASA's safety culture, including the impact on the workforce of the Artemis campaign pressures, the budget environment, and the stresses of an aging ISS. Other topics such as the long term management of astronaut health risks will be of interest, as will those topics that highlight specific safety risks of a particularly challenging nature to PMs, such as parachutes of the CCP. Throughout the year, the ASAP will continue to monitor troublesome integrated risk management areas to bolster NASA's formidable technical expertise by illuminating potentially unrecognized areas of safety process or organizational dissonance.

In closing, the Panel cannot emphasize enough how much complex and challenging work is ongoing within NASA, how demanding the environment is within which that work must be accomplished, and how much vigilance will be required to execute that work safely and effectively. The Panel commends NASA for a particularly impressive effort in 2023 to strategically advance the Agency's risk management posture.

Appendix A

Summary and Status of Aerospace Safety Advisory Panel Open Recommendations

Each previous year recommendation has an associated action color. **RED** highlights what the 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 or issue 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.

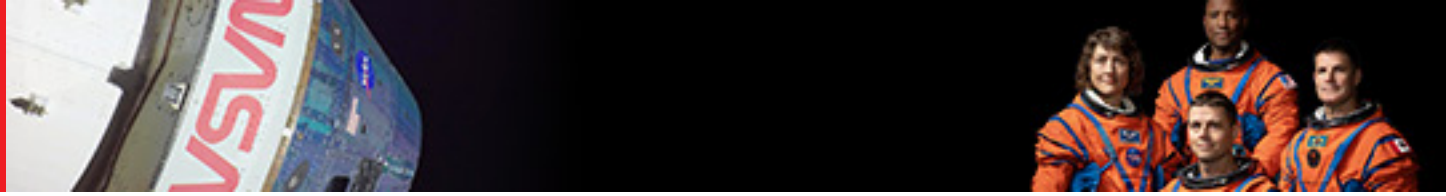
2023 Recommendations

2023-04-01: Establishment of a Comprehensive International Space Station (ISS) to Commercial Low-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 (CDISS) 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 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. The ASAP believes NASA should adopt as concerted an approach here as it did with development of the objectives for the Artemis campaign, to include clarity on the driving requirements for continuing LEO operations.

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.

Open Recommendations from Prior Years

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 event of an emergency as well as in place before the retirement of the ISS – to ensure that the station is able to be de-orbited 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.

ASAP closed the recommendation in 2020 because there was conceptual agreement on an approach and a final agreement with the Russian Space Agency was described as 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.

This recommendation is **OPEN**.

Response: NASA concurs with the action to provide details of the ISS deorbit plan. The current ISS deorbit plan is documented in Space Station Program (SSP) 51066 "ISS Deorbit Strategy and Contingency Action Plan." NASA updates it regularly with details of the technical strategy for ISS deorbit, updated analysis results associated with deorbit, as well as existing assets that can support ISS deorbit operations. NASA has made progress toward solicitation of a U.S. Deorbit Vehicle (USDV) to serve as the nominal ISS deorbit capability to be used in conjunction with Russian thrusters, while still coordinating with Roscosmos on sustaining ISS operations until nominal deorbit and providing contingency deorbit capability with existing Progress and Service Module thrusters.

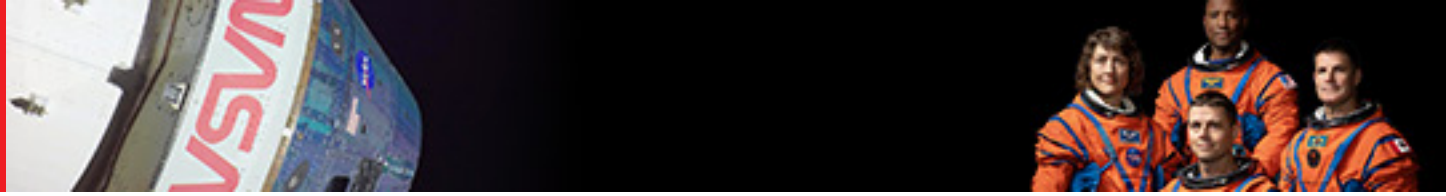
2021-05-01: Development of Agency Strategic Vision for the Future of Space Explorations and Operations

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 — well 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.

This recommendation is **OPEN**.

Response: NASA continues to make good progress on this action with an anticipated path to closure in the next calendar year. The Panel is looking for additional insight and details on the action plans associated with operationalizing the *NASA 2040* initiative and on the agency's thought process and criteria associated with Make, Manage, or Buy decisions, and particularly how risk and safety are considered in these processes.

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 Agency-wide 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 — 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.

It is clear in 2023 that NASA has made remarkable strides in deliberate alignment and strategic decision making and is taking deliberate and important steps to intentionally use the full and open forums to maximize transparency and engagement, articulate and adjudicate agency-level priorities and strategy, and to deliberately align to Agency goals.

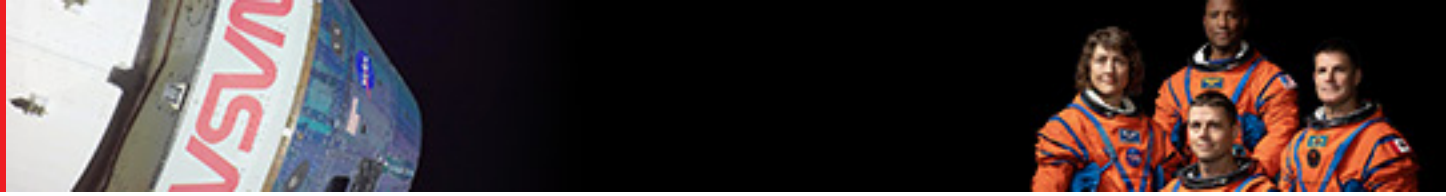
The last step the Panel recommends in closing this governance recommendation is about accountability. The ASAP remains interested in better understanding the methods by which agency-level NASA leaders hold Center Directors and Program Managers accountable to achieve agency objectives, across a full spectrum of risks.

This recommendation is **OPEN**.

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.

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 designation — 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.

This recommendation is **OPEN**.

Response: The chairman of the Senate Committee on Commerce, Science, and Transportation has introduced the Space Preservation and Conjunction Emergency (SPACE) Act, which would authorize the Department of Commerce to provide space situational awareness services to civil, commercial, and international space operators. However, even if the SPACE Act is eventually approved by Congress, and signed into law by the President, it would still be necessary for Congress to provide the necessary budget and staffing resources through the appropriations process before any significant actions could be taken to implement the Act.

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

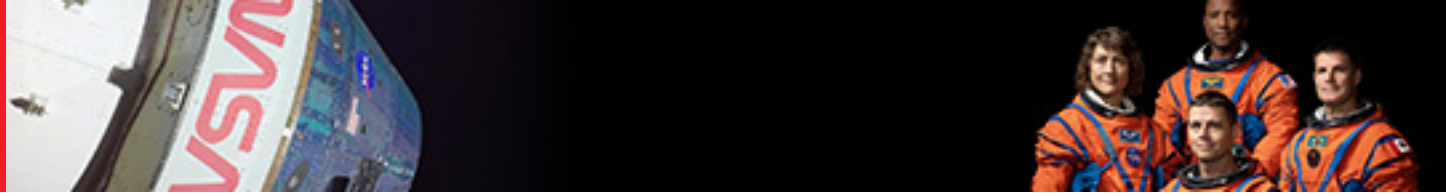
Finding: The ASAP has become increasingly concerned with the risk posture that NASA has adapted regarding the current EMUs used in International Space Station (ISS) operations and has concluded that the current EMUs are now outside their design life.

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.

This recommendation is **OPEN**.

Response: Over the past year, NASA has executed its acquisition for an EMU flight suit using a creative indefinite delivery/indefinite quantity approach that provides 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. The Panel views



this as good advancement on both requirements but will keep this recommendation open to observe further progress and execution in 2024.

2015-05-02: Human Space Flight Mishap

Finding: The Commercial Crew Program (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 Spaceflight 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.

This recommendation is **OPEN**.

Response: NASA originally responded on 4/30/16, concurring with the recommendation. The response stated that NASA was reaching out to the Federal Aviation Administration 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 3/20/17 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. The ASAP provided a written response on 9/8/17, followed by subsequent discussions during which the ASAP provided alternate solutions to which NASA provided a third response on 3/15/18. NASA and 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.

Appendix B

Aerospace Safety Advisory Panel Recommendations Closed in 2023

2021-05-03: Establishment of an Artemis Integrated Program

Finding: NASA has deviated from previous program management "best practices" that have been hallmarks of successful strategic programs. During this past year, the Panel had numerous opportunities, during Quarterly meetings as well as special discussions, to better understand how the myriad of programs and projects that collectively contribute to the objectives of Artemis will be brought together as a cohesive campaign, and the Panel notes several deviations from NASA's history that give cause for concern. The ASAP finds three areas of concern:

1. There is no top-level Artemis program, and therefore no Artemis Program Manager, to provide comprehensive and aligned integrated guidance that directs resources of all Artemis programs and projects in a cohesive manner to manage the overall risk.
2. No Artemis Prime Integrating Contractor (PIC) exists in support of the NASA workforce.
3. An unprecedented mix of acquisition approaches presents risk management challenges.

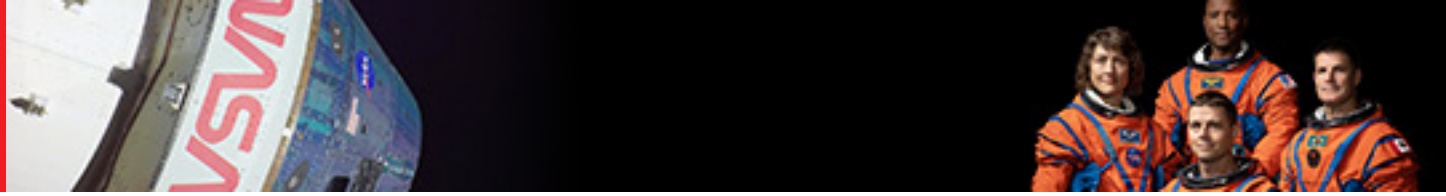
Recommendation: NASA should manage Artemis as an integrated program with top-down alignment, and designate a Program Manager endowed with authority, responsibility, and accountability, along with a robust bottoms-up, collaborative feedback process for both Systems Engineering and Integration (SE&I) and risk management.

Closure Rationale: As discussed in Section III.C. of this report, NASA has established a Program Manager for the Artemis Program.

This recommendation is **CLOSED**.

2018-04-01: Required Actions for Crewed Flight Test Risk Reduction

Finding: There are serious challenges to the current launch schedules for both SpaceX and Boeing. For SpaceX, one challenge is the lack of final resolution of the composite overwrapped pressure vessel failures, which are generally considered to have been involved in a launch pad accident and which affect the total safety of the "load-and-go" launch concept. In addition to this issue, recent parachute performance, both during the Commercial Crew Program qualification-testing regimen and during the resupply contract, indicates potential problems with parachute designs. A potential redesign, which may be required, would drive a requirement for additional qualification and certification testing. The Boeing program also holds key risk items, some of which have emerged during the qualification test program; specifically: parachutes launch abort engine hot fire testing, and pyrotechnic separation bolt initiator device qualification failures. The burn-down curve of certification products remains steep for verification and validation, and much work



is ahead. Schedule pressures and the desire to launch pose a potential for the uncrewed test flights to occur without all the critical content to fulfill the role of risk reduction for crewed flight.

Recommendation: NASA should confirm and then clearly communicate the required content and configuration for the upcoming CCP test flights — Demo-1 and Orbital Flight Test (OFT) — specifically, those items that must be successfully demonstrated prior to the first crewed flights.

Closure Rationale: The recommendation for Crewed Flight Test (CFT) Risk Reduction was specific to the Demo-1 and OFT test flights, both of which have been flown successfully. NASA and SpaceX successfully incorporated lessons learned from the Demo-1 test flight to safely fly the initial crewed test flight and subsequent operational crewed missions on a regular basis.

The Boeing OFT identified issues that needed to be addressed before the crew could be safely flown. The issues identified are being thoroughly addressed and have laid the groundwork for the path to a successful crewed flight test. Although schedule pressure always exists, Boeing and NASA have demonstrated the willingness to adjust the launch date to ensure that the Starliner flight will be safe for CFT. The combination of NASA's and Boeing's quality control processes have identified significant issues that NASA and Boeing management have demonstrated the willingness to allocate the appropriate number of resources and time required to be thoroughly mitigated.

This recommendation is **CLOSED**.

2018-04-02: Action to Ensure US Access to the International Space Station (ISS) Given Commercial Crew Program (CCP) Schedule Risk

Finding: As outlined in the Finding for Recommendation 2018-04-01, serious technical difficulties and challenges pose considerable risk to both providers' schedules for crew transportation to the ISS in calendar year 2019. Currently, there are no Soyuz seats available for US crew after 2019.

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

Closure Rationale: As noted in NASAs response, the Agency has taken tangible action to ensure US continued presence on ISS through CCP and Russian Soyuz missions.

This recommendation is **CLOSED**.

Appendix C

Aerospace Safety Advisory Panel Members

Dr. Patricia Sanders

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

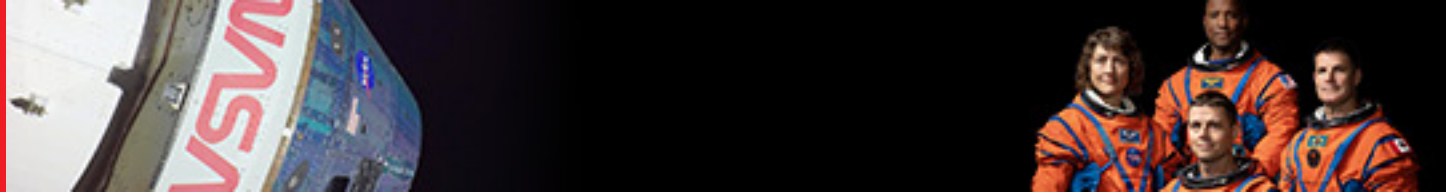
Dr. Patricia Sanders is now an independent aerospace consultant after having been a Senior Executive with the DoD and retiring from the Federal Government after thirty-four years of service with experience in the management of complex technical programs, leadership of large and diverse organizations, and development and execution of policy in the Office of the Secretary of Defense.

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

After teaching at Boise State University and the University of Utah, Dr. Sanders began her national security career with the US Army in Germany in 1974. She progressed through several challenging positions including management of several Defense acquisition programs; positions with the Air Force Operational Test Center in space system and aircraft avionic testing; Chief Scientist for the Command, Control, and Communications Countermeasures Joint Test Force; and Director of Analysis for the US Space Command.

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

Dr. Sanders has actively supported professional, academic, and civic organizations, serving on numerous executive boards. She is a Fellow of the American Institute of Aeronautics and Astronautics (AIAA) and has received three Presidential Rank Awards for executive achievements. She was awarded the Allen R. Matthews



Award for significant accomplishments in test and evaluation along with the AIAA DeFlorez Award for Modeling and Simulation, which recognizes achievements in its aerospace applications.

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 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 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 for Research, Development, Test and Evaluation 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 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 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 a Master of Science 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 Level III in Program Management, 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
- Former Senior Advisor to the Administrator for Homeland Security at NASA

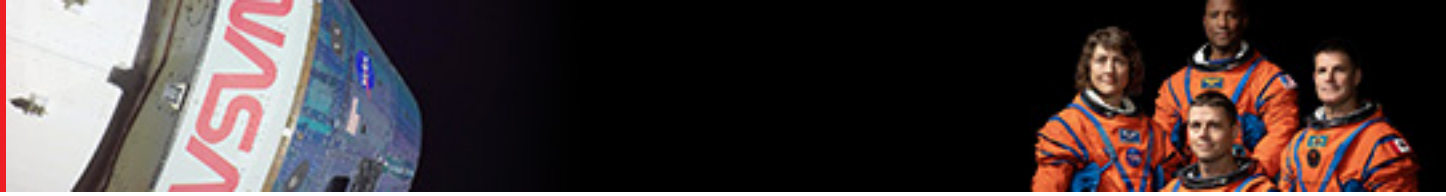
Dr. Amy Donahue is Provost and Chief Academic Officer at the United States Coast Guard Academy. She is responsible for the quality and effectiveness of the Academy's academic enterprise in support of its core mission to educate leaders of character who serve as officers in the Coast Guard. Dr. Donahue is also professor emeritus of public policy at the University of Connecticut (UConn). Her research as a social scientist 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 for five years, leading a department that included a nationally respected Master of Public Administration program, top-ranked in public finance. She advised the Chancellor of Louisiana State University (LSU) immediately following Hurricane Katrina and was the founding director of LSU's Stephenson Disaster Management Institute, a research institute focused on the challenges of managing large disaster responses. 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. She was the agency's liaison to the Department of Homeland Security and the Homeland Security Council and was responsible for identifying opportunities for NASA to contribute to homeland security efforts across government. 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 for the 706th Main Support Battalion, and as Chief of Mobilization, Education,



Training, and Security for Bassett Army Hospital. She moved on to manage a 911 communications center, and to volunteer and work part-time as a firefighter and medic in Fairbanks, Alaska, and upstate New York.

Dr. Donahue holds her Ph.D. in Public Administration and her Master of Public Administration 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.

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

- 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, FL
- Former NASA Astronaut
- Former Air Force Flight Test Engineer

Lieutenant General Susan J. Helms, United States Air Force (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, a world record. She was inducted into the Astronaut Hall of Fame in 2011.

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 an author and speaker focused on the leadership principles that are critical in creating and leading high-performing teams. During his 25 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 24 missions as a Flight Director from 1996 through 2005, culminating as the Lead Shuttle Flight Director for the return to flight on STS-114 after the Columbia accident.

After a series of senior leadership positions, 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.

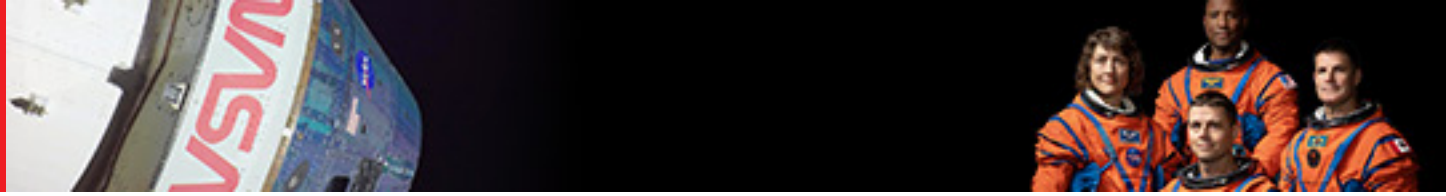
Before his work with NASA, Mr. Hill served in the USAF in military satellite operations. He earned his Bachelor and Master of Science degrees in aerospace engineering from Texas A&M University in 1984 and 1985, respectively, and was a member of the Corps of Cadets.

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 a Stellar Award, and selection as one of the Marshall Goldsmith 100 Coaches.

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, vice president and capture lead for the OmegA launch system, 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 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 was selected into the NASA Astronaut Hall of Fame in 2015.

Mr. Rominger was commissioned as a naval officer in 1979. During his 26 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 35 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 for Space, Aerospace and Engineering at University of Colorado
- Founding executive and Former Head of Sierra Nevada Space Systems
- Founding member and past Chairman of the Commercial Spaceflight Federation
- Founder and Chairman of eSpace, a nonprofit

Dr. Mark N. Sirangelo currently is the Scholar in Residence for Space, Aerospace and Engineering at 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 career, having led teams that have successfully managed billions of dollars of space programs for more than 300 US-based space missions. In addition to academia, he provides industry advisory and board services through his company QuanStar Advisors, LLC.

In the space industry, he was the founding executive and head of Sierra Nevada Space Systems for over ten years until 2018. Previously, Dr. Sirangelo was the Chairman and Chief Executive Officer of SpaceDev, a publicly traded commercial space company that he grew from an early stage until its merger with Sierra Nevada Corporation. SpaceDev and SNC had many space firsts, including being on the inaugural winning X-Prize team and the design, build, launch, and operation of the first small satellites. He was a founding member and past Chairman of the Commercial Spaceflight Federation, which currently represents more than

eighty-five space organizations. He has been inducted as a Fellow of the American Institute of Aeronautics and Astronautics and 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, a cabinet-level position. He is the most recent past Chairman of the US Department of Defense's Defense Innovation Board, which provides 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 and personal awards. These include being inducted into the Space Foundation's and NASA's Technology Hall of Fame, the World's Top 10 Innovative Space Companies by Fast Company, being named Manufacturer Builder of the Year by ColoradoBiz magazine, Best Place to Work by the Denver Business Journal, Inc. Magazine's top 200 companies, Defense Industry's Fast Track 50, Deloitte's Fast Track 500, and selected as a finalist in Ernst & Young's Entrepreneur of the Year.

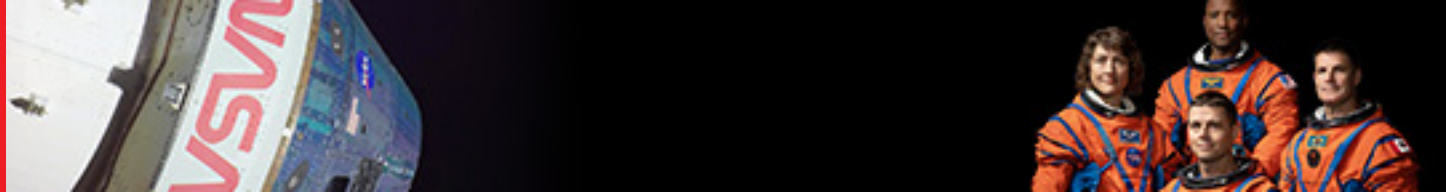
One of the ways Dr. Sirangelo gives back to the space industry is as founder and Chairman of eSpace, a nonprofit that supports the startup and growth of space technology companies. As a personal passion, he has worked for over two decades to make the world a safer place for children as a founding Board 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 Bachelor of Science, Master in Business Administration, and Doctorate degrees and has served his country proudly as a US Army officer.

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

- Examinations Director, Board of Certified Safety Professionals (BCSP)
- President, International System Safety Society (ISSS)
- Member, Personnel Certification Accreditation Committee of the American National Standards Institute (ANSI) National Accreditation Board
- Former Vice President and Deputy Operation Manager, Science Applications International Corporation (SAIC)
- Former Chair, G-48 System Safety Committee of SAE International

Mr. David B. West is the Examinations Director at BCSP. He is responsible for activities involving the development, validation, maintenance, and administration of examinations for BCSP certification candidates in the safety, health, and environment field. He previously served as an engineer and system safety subject matter expert for SAIC in positions of increasing responsibility, including vice president, deputy operation manager, and operation-level chief technology officer. In more than twenty-eight years with SAIC, Mr. West's



work helped ensure the safety of a variety of systems and programs of national importance, including US Army crewed and uncrewed fixed-wing aircraft and helicopters, military ground vehicle immersive training systems, rocket-launching weapon systems, precision targeting systems, chemical weapons destruction facilities, uranium enrichment and other nuclear operations, super-conducting magnetic energy storage technology, petroleum refining and chemical manufacturing, the Space Station Freedom Program, Space Shuttle microgravity experiments, and the Space Shuttle range safety system.

For many years, Mr. West actively led or supported standards-developing activities for system safety and other specialty engineering disciplines. From 2010 to 2019, he chaired the G-48 System Safety Committee, currently under SAE International. He was one of the authors of the G-48 Committee's "Standard Best Practices for System Safety Program Development and Execution," GEIA-STD-0010, and was the sponsor of its first major revision. Mr. West served on BCSP's Board of Directors from 2008 to 2013 and was the Board's Treasurer from 2012 to 2013.

Mr. West is a Fellow Member of the ISSS and was awarded its highest honor, the Professional Development Award, in 2013. He was also named the ISSS Manager of the Year in 2010. He has been an invited speaker on system safety topics at several national and international events, including the 1st International Helicopter Safety Symposium in 2005, the Federal Aviation Administration's 9th Annual Commercial Space Transportation Conference in 2006, the Australian System Safety Conference in 2013, and numerous International System Safety Conferences since 2001.

Mr. West earned a B.S. in nuclear engineering from the University of Cincinnati. He holds the Certified Safety Professional, Associate Safety Professional, and Certified Hazardous Materials Manager credentials, and he is a registered Professional Engineer.

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

- Health Director and 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 Health Director and Medical Consultant in the Virginia Department of Health. His duties include serving as a Health Director for Virginia public health districts and providing medical consultation services to public health districts without a physician on staff. 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 twenty seven years in the US Air Force 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.

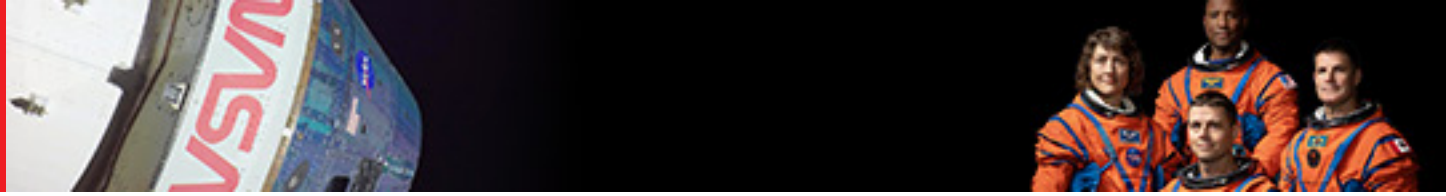
Dr. Williams received a B.S. degree from the College of William and Mary in 1975, as well as an MD degree in 1979 and a Master of Public Health degree in 1996, both from Virginia Commonwealth University. He completed general surgery residency at Wright State University in 1984 and aerospace medicine/occupational 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 Seniors Executive Service Presidential Rank Award, the W. Randolph Lovelace Award, the Forrest M. and Pamela Bird Award, the NASA Exceptional Leadership Medal, and the NASA Distinguished Service Medal. He has contributed to and published numerous articles and book chapters in the medical literature.

Aerospace Safety Advisory Panel Staff Members

Ms. Carol Hamilton

- ASAP Executive Director

Ms. Carol Hamilton, Executive Director of the ASAP since 2015, has specialized in system safety engineering for more than 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

- ASAP Administrative Officer

Ms. Lisa Hackley has worked at NASA Headquarters for more than 29 years, providing administrative support for numerous mission directorates and divisions, including the Office of Space Flight (now Human Operations and Exploration), the Office of Life and Microgravity Science and Applications (now Space Life and Physical Sciences), the Office of Biological and Physical Research, and the Office of International and Interagency Relations (OIIR). Prior to joining the Advisory Committee Management Division 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

- ASAP Technical Writer

Ms. Ashley Mae is an accomplished trauma nurse and technical writer with over a decade of experience, specializing in medical, scientific, and educational content. Holding a Bachelor of Science in Nursing from Georgia Southern University and a Master of Science in Nursing Education from Western Governors 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. Moreover, Ms. Mae possesses more than five years of experience in nursing education. This background has equipped her with a deep understanding of educational methodologies, enabling the effective translation of complex medical and scientific concepts into comprehensive and accessible technical documentation. Through her diverse background, she brings a unique blend of practical healthcare experience and pedagogical expertise to her technical writing, ensuring accuracy, clarity, and relevance in all written materials.

Front cover: *(November 28, 2022) On flight day 13, Orion reached its maximum distance from Earth during the Artemis I mission when it was 268,563 miles away from our home planet. Orion has now traveled farther than any other spacecraft built for humans.*

Orion captured Earth rising behind the Moon following its second close flyby above the lunar surface as the spacecraft trekked toward home.

Official crew portrait for Artemis II, from left: NASA Astronauts Christina Koch, Victor Glover, Reid Wiseman, Canadian Space Agency Astronaut Jeremy Hansen.

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