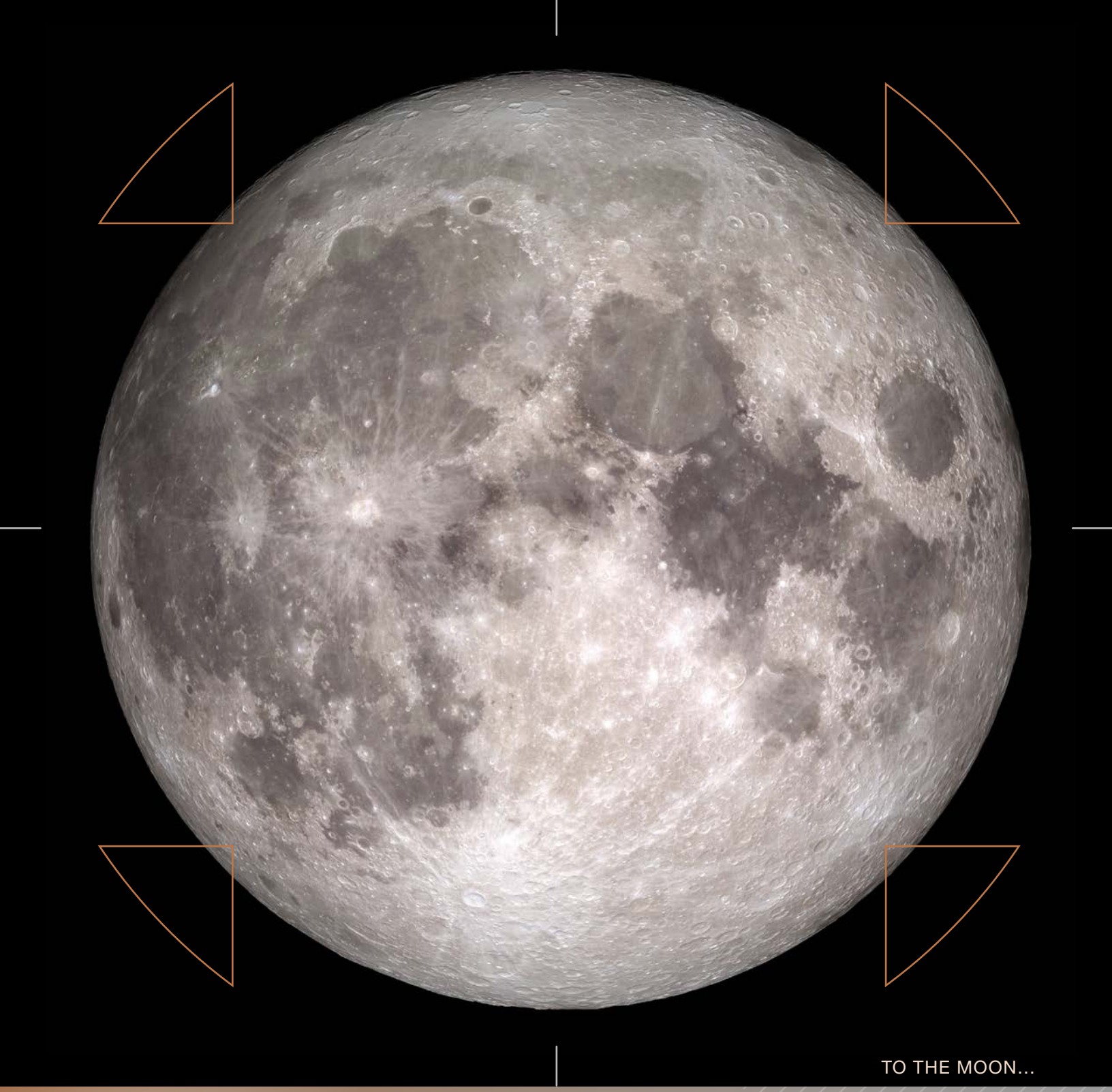

TO THE MOON...

AEROSPACE SAFETY ADVISORY PANEL

Annual Report FOR 2021

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

January 1, 2022

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

Dear Sen. 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 2021 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 2021 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.

Since its creation, NASA has been responsible for some truly remarkable accomplishments in science, engineering, and exploration. Sixty years of NASA's efforts and U.S. government investments have been instrumental in the establishment of the foundational knowledge leveraged by the world. But past accomplishments do not guarantee future success, and the space sector, both domestically and internationally, is rapidly transforming. More nations are engaged in space activities than at any point in history, and private industry is recognizing the economic value of the space domain.

The rapid changes occurring in space technology, investment, and operations define an inflection point for the space sector. As NASA looks to the future and moves to expand human knowledge and operational capabilities beyond LEO, it must recognize and adapt to the new environment and decide strategically how to forge humanity's path outward while managing the risks in an appropriate manner.

The Panel believes that how NASA manages human space flight programs can have a significant impact on the risks associated with those programs. We believe that NASA's vision for the future, and a clear definition of how it will evaluate and make decisions related to risk, are extremely important factors in ensuring human space flight safety. As a result, the primary focus of this report is the urgent need for NASA to strategically define its future role and articulate a vision and a set of guiding principles to direct its efforts. We are proposing three formal recommendations to that end.

I submit the ASAP Annual Report for 2021 with respect and appreciation.

Sincerely,

Dr. Patricia Sanders
Chair, Aerospace Safety Advisory Panel

Enclosure

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

January 1, 2022

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

Dear Madam President:

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

January 1, 2022

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

Dear Madam Speaker:

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Sincerely,

Dr. Patricia Sanders
Chair, Aerospace Safety Advisory Panel

Enclosure

Contents

The ASAP Charter and Quarterly Meeting Minutes can be found at *https://oiir.hq.nasa.gov/asap/*.

Preface

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

This report highlights the issues and concerns the Panel identified or raised during its activities over the past year. The full text of the recommendations submitted to the Administrator during 2021 is included as Appendix A, along with the Panel's open recommendations from prior years. Rationale for recommendations closed in 2021 is included as Appendix B. The Panel's issues, concerns, and recommendations are based upon the ASAP fact-finding and quarterly public meetings; insight visits and meetings; direct observations of NASA operations and decision-making; discussions with NASA management, employees, and contractors; and the Panel members' expertise.

I. Introduction and Overview

Throughout 2021, in a series of insight and fact-finding discussions and our quarterly meetings—all conducted virtually in deference to the ongoing pandemic impact—we both explored the status of NASA's ongoing program of work and focused on the longer term, strategic posture of the Agency to address risk management. As a result, this report continues our focus on strategic issues and their bearing on current development, exploration, and operational matters.

This report discusses why the ASAP continues to recommend that NASA provide answers to the strategic questions we posed in our 2020 Annual Report, and based on that strategic self-inspection, address three specific recommendations that we make in this year's Report.

We also reiterate our past advice to Congress with respect to the actions we believe must be taken for the safety of space operations in the evolving environment.

II. Problem/Opportunity Statement

Since its creation on October 1, 1958, NASA has been responsible for some truly remarkable accomplishments in science, engineering, and exploration. As an organization, it is admired around the world, and it regularly wins awards such as "The Best Place to Work in the Federal Government." However, past achievement does not guarantee future success. NASA has also had its share of failures, some of which have come with costly lessons that must inform future choices. 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.

As the ASAP discussed in last year's annual report, how NASA conducts its human space flight programs has evolved. From its founding, and for much of its history, NASA took responsibility for defining, directing, and executing almost all of its major programs. Later, NASA made conscious decisions to share responsibility for managing significant portions of certain programs with industry. More recently, several of NASA's key programs have been almost entirely managed by industry. This evolution in who has what responsibility occurred in response to several drivers, including:

- The belief that it may allow for lower program costs.
- The potential to significantly shorten development schedules.
- A deliberate strategy to turn some activities over to industry to enable NASA to focus its efforts and its budgets on more challenging tasks, including exploration beyond low-Earth orbit (LEO).

The rebalancing of roles and responsibilities between NASA and industry has generally succeeded, but this trend has changed how NASA executes its mission. Specifically:

- For a significant portion of its program portfolio, NASA is no longer responsible for deciding how systems are designed, developed, and tested.
- Increasingly, NASA is becoming a customer rather than an owner/operator.
- Rather than directing all human spaceflight programs, NASA is more frequently engaging with—and relying on—industry and international partners.

If these trends continue, which seems likely, the Panel believes it is crucial for NASA to strategically evaluate the path ahead and determine the future shape of the organization. Once the Agency has clarified a vision and strategy, it should then make the decisions, and take the necessary actions, to enable it to accomplish the required transformation. And, regardless of the vision NASA conceives for its future, the Agency must also operate as efficiently as possible to manage fixed costs and to maximize the budget available for mission-related work.

As part of this report, the Panel has identified a series of issues that NASA will need to address with respect to its plans and aspirations for the future; how it intends to interact with both commercial and international partners; its risk management approach; and its changing workforce and infrastructure needs. We offer three specific top-level recommendations as improvement opportunities related to NASA's Strategic Vision and Guiding Principles, Agency Governance, and Program Management.

A. Inflection Point—Why is Now the Right Time to Address These Issues?

The rapid changes occurring in space technology, investment, and operations—and the growth of a commercial sector interested in pursuits beyond those driven by government requirements—define an inflection point for the space sector. In the past, space activity was primarily sourced directly by government-defined missions. In the future, the government will be only one of many customers, and industry will develop and bring to bear an increasingly broad and technologically sophisticated set of capabilities. As this transformation progresses, it is hard to predict the array of human space flight activities that might be under way 20 years from now. In two decades, LEO might be crowded with multiple commercial space stations, a propellant depot or two, and numerous solar power satellites, with a fleet of space tugs carrying crew and cargo back and forth through cis-lunar space. The south pole of the Moon could be the site of a major scientific research base, complete with habitats and mining sites. Other experiment stations might operate simultaneously in multiple locations. It is certainly possible that before two decades pass, astronauts will have landed on Mars.

Funding such endeavors will obviously take considerable resources. However, history suggests (as shown in **Figure 1**) it is unlikely NASA's budget will ever again exceed 1% of the federal budget, as it did during the lead-up to the Apollo Program. Consequently, it will not be possible for NASA to single-handedly carry out all of the missions now envisioned. Considering its ambitious goals and constrained budget, for NASA—and hence the United States—to continue to play a strategic leadership role in space, the Agency must transform. While private industry efforts are an ever more important factor in the U.S. government's future endeavors, the commercial sector alone has not, and will not, be

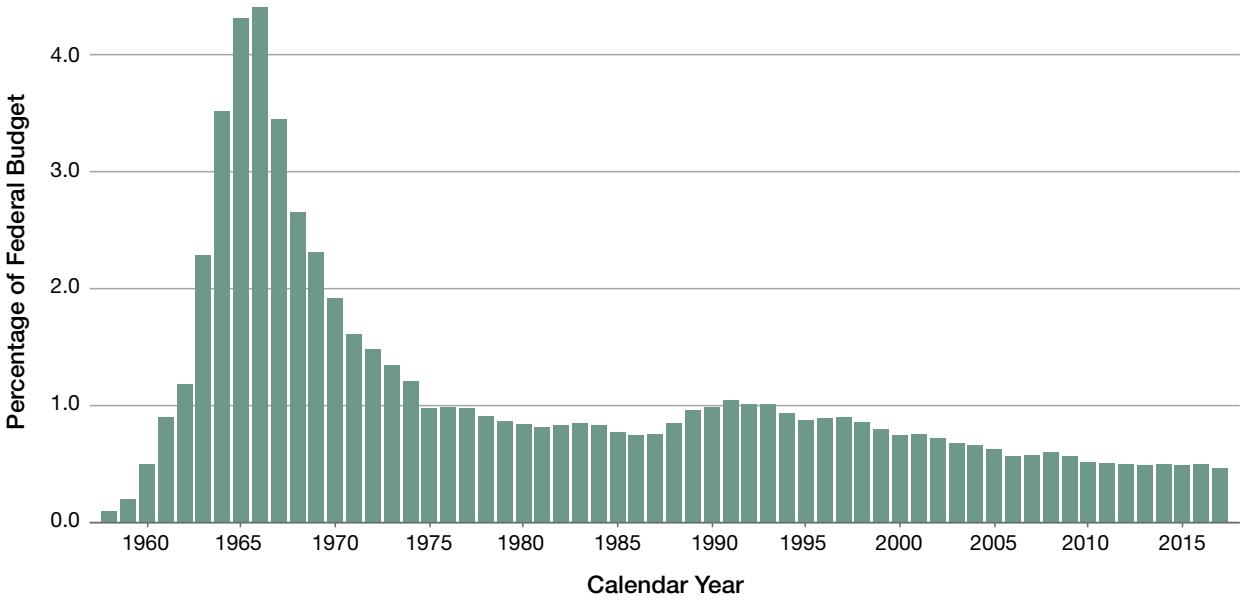

FIGURE 1. Historical NASA Budgets as a Percent of the Federal Budget

the vehicle that drives national goals. Consequently, the Agency will need to operate differently—from strategic planning and how it approaches program management, to workforce development, facility maintenance, acquisition strategies, contract types, and partnerships.

Drivers for the need to transform include:

- Missions to the Moon and Mars are significantly more complex than the objectives of previous programs, with multiple launches and a variety of vehicles required for each expedition.
- The increase in mission complexity requires considerably more integration "touchpoints" between supporting programs, leading to increased oversight and program expenses.
- Sustained lunar and Martian missions will involve significantly greater risk than NASA's previous human space flight experiences in the LEO regime. The global space community still has much to learn about supporting humans on other planetary bodies for long durations.
- The pace of technological change will almost certainly continue to increase, requiring designs and systems that are flexible enough to integrate advantageous advancements.
- The aerospace industry has become much more diverse and innovative, and companies are willing and able to make major contributions as contractors, service providers, or partners.
- Having benefitted from a positive experience with the International Space Station (ISS), the international community has made it clear that it would like to work with NASA on future exploration programs.

B. Is This Really a Safety Issue?

As described in the ASAP charter, the Panel is tasked to provide advice and make recommendations on matters related to safety. Changes in how NASA manages human space flight programs have a significant impact on the risks associated with those programs. As one example, the overall strategy NASA decides to use for a particular program—whether to "make, manage, or buy"—has major implications for the kind of expertise and experience the Agency's workforce will need to successfully execute the program and manage the associated risks.

The Panel believes that NASA's vision for the future, and a clear definition of how it will evaluate and make decisions related to risk (in addition to how it will manage and execute programs), are extremely important factors in ensuring human space flight safety. As a result, the primary focus of this report is the urgent need for NASA to strategically define its future role and articulate a vision and a set of guiding principles to direct its efforts.

As NASA continues to evolve and define its future role, it is important for the Agency and its stakeholders—Congress, other Executive branch entities, the private sector, and the taxpayers—to understand the context in which NASA has successfully operated for the past 50 years. By having a clear understanding of what drove, and continues to drive, Agency culture and thinking, NASA and its stakeholder community can work intentionally to chart a meaningful and impactful role for the Agency in the future. Ignoring the external forces and environment in which the Agency must function will place NASA in a tenuous position going forward, which in turn will impact how safely and successfully it will be able to carry out U.S. government missions in space.

C. Challenges of NASA's Internal and External Environments

NASA's structure, organizational dynamics, and workforce culture are grounded in how the Agency was formed and shaped by the dynamics of its stakeholders. The Agency was established before society had any foundational engineering and operational experience related to sending humans to live and work in space. Consequently, NASA had to create the workforce and knowledge necessary to engage in human space flight safely and successfully. As the complex undertaking of sending humans to the Moon evolved during the 1960s, NASA centers each invested in specific technical or operational expertise—a defining feature of the very same centers that is still true today. As NASA grew and established new programs, the work divided across the different centers shifted and evolved but was still fundamentally driven by the early distribution of technical expertise. At times, however, a competitive dynamic emerged between NASA centers, particularly those that primarily support human space flight, often energized by local stakeholders.

Over the decades, at various times with varying amounts of success, NASA leadership has sought to create an Agency-wide identity and foster greater coordination. There remains, however, a very strong and separate culture at each NASA Center. This drives the Centers to prioritize their own goals rather than those of the overall Agency, and it 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.

Today, more than six decades after its founding, the Agency is at an inflection point. The space industry has matured and has developed a breadth and depth of capabilities available at lower costs than NASA would incur to develop or maintain those capabilities itself. Because industry capabilities are so enhanced, NASA is challenged to reduce its costs for those programs it chooses to develop internally. But the Agency's structure, culture, and stakeholder dynamics have created significant drag on its ability to achieve this goal.

In this context, NASA is slowly adapting its approaches to industry management. NASA's efforts and learning have progressed at a tactical level through case-by-case execution, however. A broader, more comprehensive Agency-wide evolutionary approach is required. NASA must grow more efficient and flexible—not only to meet stakeholder expectations, but also to operate in an environment where the private sector is emerging as a major independent contributor to the execution of NASA missions—while still continuing to manage risk as effectively as it has in the past.

In addition, as NASA adapts internally to remain successful in its changing external environment, the expectations of its stakeholder communities—specifically Congress and the Executive Branch—must also adapt. The Panel has stressed the importance of constancy of purpose and its role in the ability of the Agency to manage risk intelligently and proactively. Not only do consistency and clarity of objectives help the Agency plan more efficiently, but they also send a clear message to the workforce about the Agency's direction, providing focus and background for decision-making at all levels. Constant and abrupt changes in direction create inefficiencies in planning and execution that create confusion and uncertainty in the workforce and dilute the focus in decision-making, all of which increase cost and risk. Importantly, over the past two Administrations, the Moon has remained steady as a primary mission. Prior transitions were not as smooth, however.

Disruptive changes in direction not only decrease the ability of the Agency to operate efficiently, but they also shape internal NASA culture. To illustrate (see **Figure 2**), as the Space Shuttle program was ending, the Constellation program gave the Agency a clear mandate to return to the Moon. When the Constellation program was cancelled, after an Administration-level review of program performance, the Agency was redirected to an asteroid landing mission, an objective that made less technical sense for a long-term development of interplanetary capability. When the asteroid objective lost traction within a few years, it created a ripple of uncertainty and the loss of a strong mission focus in the workforce that echoes to this day. The abruptness of these changes in direction for NASA's primary touchstone program caught the whole community—but especially the NASA workforce—by surprise. Confusing communication about the Administration's rationale and the lack of supporting technical data for the asteroid mission, especially for an agency that bases its very successes on a strong technical culture, created a lack of trust. And, to many in the NASA workforce, the Moon then became a forbidden subject of consideration, even though the Moon was rightly perceived as the next technically advantaged step and logical risk management choice in human exploration.

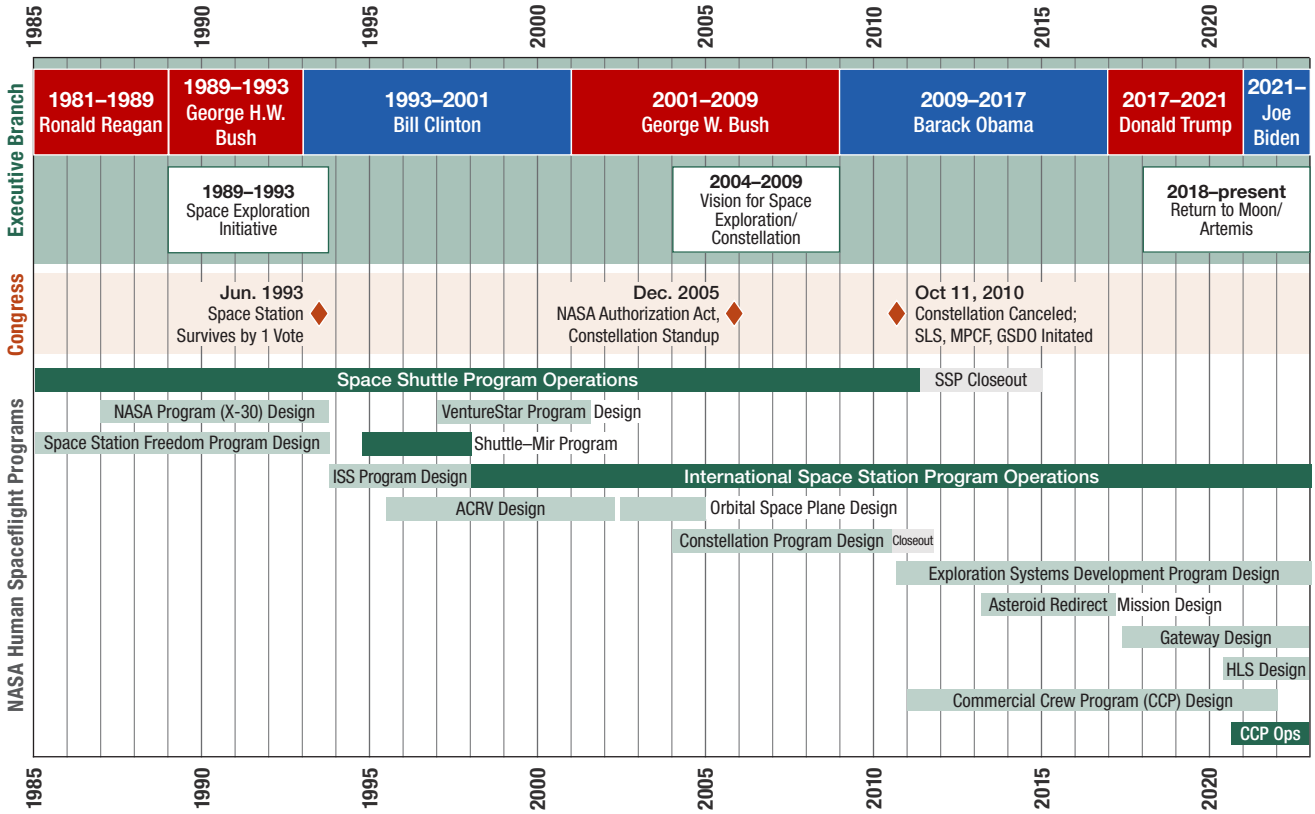

FIGURE 2. Historical Changes in Program Direction

The cultural dynamics prompted by the instability of purpose and the disconnect between purpose and technical rationale now appear to be normalized into the organizational culture. NASA leaders, unable to discuss a comprehensive lunar program, were driven to create tools and capabilities outside the traditional program context the Agency had always used to manage complex integrated capabilities throughout its history. Consequently, the Exploration Ground Systems (EGS), Orion, and the Space Launch System (SLS) were established as three individual programs, each with their own processes, structures, and management approaches, rather than being integrated as what previously would have been a single program. These three individual programs were then distributed across the three major NASA human space flight centers to make the resource allocation equitable and to satisfy stakeholder requirements.

Unfortunately, this approach left a critical gap in the system-of-systems integration process that is usually filled by having a single overarching program umbrella with requisite program authorities and integration responsibilities. In the absence of a formal program umbrella, NASA Headquarters created a bottom-up integration effort, which required the individual programs to negotiate among themselves.

This is a difficult proposition for managing design and operational changes that allocate risk to different elements, which then impacts individual program cost and schedule. The Panel notes that such an approach often prioritizes consensus, rather than decision-making by an accountable leader, which makes resolution of tough integration, resource, and risk management issues even more challenging.

In adopting this disaggregated, decentralized program structure between SLS, EGS, and Orion, with the view that it is a manageable alternative to the familiar and effective program framework that served it well for the Apollo, STS, and ISS programs, NASA has seemed to overlook the negative impacts to cohesive integrated risk management. In essence, it appears that the cancellation of the Constellation program has led to a cautious stance among NASA leaders driven by the assumption that having an Apollo-like program now is a problematic political optic, and like Constellation, a possible target for cancellation by a future Administration. In effect, NASA has accepted the disaggregated program structure as normal, and is now propagating this structure as a preferred business and risk management model, even though it is essentially an untried approach for an integrated systems engineering effort of this magnitude and complexity.

Thus, behavior that was instantiated as a coping mechanism for unstable political guidance has become institutionalized—as has the embedded uncertainty in risk management. Furthermore, the Agency is attempting to manage the risk in the structure it has adopted without deliberately assessing why the structure is at least equivalent to, if not an improvement to, a more familiar structure, and whether it should be advanced as a wholly new program approach.

Beyond this, pressures from myriad stakeholders across the Executive and Legislative branches of government mean NASA faces other dynamics that impact its ability to execute. These stakeholders, from the Office of Management and Budget, to separate Congressional delegations/offices, have various agendas and can generate competing and occasionally contradictory directives for the Agency. Each stakeholder's priorities drive particular tasks and workflows that undercut holistic optimization at the Agency level. This strains NASA's ability to manage its own internal costs, especially those associated with infrastructure and labor. While understandable that individual stakeholders emphasize their own interests and concerns, the simultaneous insistence across all stakeholders that NASA execute an increasingly large number of very complex missions creates an environment for increased risk and unintended impacts on safety. With constrained resources come limitations on the deep technical examination necessary to fully understand integrated mission risk. It is unrealistic to expect NASA to operate efficiently when pulled in so many different directions. Therefore, it is hard for the nation, and thus the Agency, to have a coherent conversation about national objectives, let alone formulate an approach on how to meet those objectives.

The Constellation program provides another example of this dynamic. One of the major factors cited for the program's cancellation was that it was unacceptably over budget. One reason the Constellation budget became inflated was because NASA's fixed costs, previously absorbed by the Space Shuttle program, were planned to be transferred to the Constellation program—along with the obsolete, and in some cases, unnecessary infrastructure that drove costs higher—simply because

Constellation was the next long-term NASA human space flight program. That extra burden imposed on the Constellation program strained the budget—a budget originally allocated for a developmental program, not designed for the additional labor and facilities costs it inherited. Exacerbating this problem was the fact that as the Shuttle program was being retired, the Agency was directed to retain all civil servants.

And finally, the national budget formulation process influences NASA's ability to operate more efficiently, and directly impacts risk and safety, just as it does other agencies. Like other agencies, NASA receives its budget allocation annually. For the last decade, that process has been routinely delayed, requiring the Agency to work in a constant environment of budget uncertainty. Although it is well understood that the budget profile for a complex engineering system requires significantly more up-front investment during the design and development phase, NASA must manage its programs with essentially flat line spending profiles from year-to-year (see **Figure 3**). In an uncertain and constrained

NASA Continuing Resolution History
Fiscal Year (FY) 2008–2022

	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
CR-1	PL 110-92	PL 110-329	PL 111-68	PL 111-242	PL 112-33	PL 112-75	PL 113-44	PL 113-164	PL 114-53	PL 114-223	PL 115-56	PL 115-245	PL 116-59	PL 116-159	PL 117-43
CR-2	PL 110-116	PL 111-6	PL 111-88	PL 111-290	PL 112-36		PL 113-67	PL 113-202	PL 114-96	PL 114-254	PL 115-90	* PL 115-298	PL 116-69	PL 116-215	PL 117-70
CR-3	PL 110-137			PL 111-317	PL 112-55		PL 113-73	PL 113-203	PL 114-100	PL 115-30	PL 115-96	PL 116-5		PL 116-225	
CR-4	PL 110-149			PL 111-322	PL 112-67						PL 115-120			PL 116-226	
CR-5				PL 112-4	PL 112-68						PL 115-123			PL 116-246	
CR-6				PL 112-6											
CR-7				PL 112-8											
CR-8				PL 112-10											
Final Approp.	PL 110-161	PL 111-8	PL 111-117	PL 112-10	PL 112-55	PL 113-6	PL 113-76	PL 113-235	PL 114-113	PL 115-31	PL 115-141	PL 116-6	PL 116-93	PL 116-260	
Omnibus	●	●	●	●		●	●	●	●	●	●			●	
Minibus					▲							▲	▲		
Data Enacted	12/26 2007	03/11 2009	12/16 2009	04/15 2011	11/18 2011	03/26 2013	01/17 2014	12/16 2014	12/18 2015	05/05 2017	3/23 2018	2/15 2019	12/20 2019	12/27 2020	
Months Under CR	3	6	3	12	2	6	4	3	3	7	6	5	2	3	TBD

* NOTE: Lapse in appropriations for all Government agencies (including NASA) without a full-year appropriation, from 12/21/18 through 1/25/19.

FIGURE 3. NASA Continuing Resolution History—Fiscal Year (FY) 2008–2022

budget environment, engineering decisions are driven by short-term cost considerations that have long-term consequences for operations, safety, and risk posture. For example, integrated testing programs developed early on for sound technical reasons may get trimmed due to schedule and resource pressures, which increases operational risk. Optimal design solutions may be discarded to contend with immediate cost concerns, and thus thwart the opportunity to realize long-term savings and promote operational risk mitigation. Simply addressing the uncertainties and suboptimal phasing that are inherent in the current budget processes would go far toward allowing the Agency to manage risk better and make the difficult strategic decisions necessary to operate more efficiently.

While NASA must evaluate its structure, organizational dynamics, and culture to align to the new operating environment in which it finds itself, to be successful it also needs strong awareness and support from the stakeholder communities who must recognize their impact on the Agency's ability to safely execute the nation's space missions.

D. What Does Success Look Like?

In the ASAP Annual Report for 2020, we began a discussion of some strategic issues facing NASA in a rapidly evolving environment that we believe have significant impact on the safety and risk management of human space flight. In particular, we posed the following critical strategic considerations for the Agency:

- What role NASA intends to perform going forward and why.
- How the Agency will interact with both commercial and international partners.
- How the Agency will address shared risks.
- What management practices will be employed.
- How the expectations will be communicated to its partners and to its workforce.
- How effective Systems Engineering and Integration (SE&I) will be accomplished.
- What the NASA workforce of the future should look like and how it will be achieved.

As NASA begins to answer these questions and craft the vision and principles that will guide the Agency for the next several decades, the Panel offers the following recommendations to help shape their efforts.

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.

Recommendation 2021-05-02

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.

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 bottom-up, collaborative feedback process for both Systems Engineering and Integration (SE&I) and risk management.

These recommendations will be discussed in the subsequent sections of this report.

III. Strategic Vision and Guiding Principles

The ASAP's Annual Report for 2020 noted that the organizational structure, stakeholders, and characteristics associated with past NASA programs are very different from those present today (see **Figure 4**). The complexity of the missions and the variety of acquisition approaches has driven a much more challenging risk management and decision-making structure. In addition, the evolving dynamic of the human space flight sector—the many and multifaceted interactions across stakeholders, commercial suppliers, partners, and customers—creates a more challenging and complex day-to-day operating environment for NASA.

	Historical e.g., Apollo, Shuttle	**Today** e.g., Artemis, EDS, Gateway
Program Authority	NASA	NASA
Program Accountability	NASA	NASA
Program Responsibility	Solely NASA	Shared
Program Definition	Single major program	Many individual programs
Program Execution	Largely government with a single integrating contractor, international partners	Distributed, multiple suppliers, independent commercial efforts, international partners and competitors
Program Engineering	PMO Engineer, Prime contractor	Multiple, decentralized
Risk Ownership	Centralized, NASA	Decentralized, multiple owners

For today's environment…

What are NASA's guiding principles and culture for NASA success?

FIGURE 4. NASA's Historical and Present Environments and Factors

Of particular importance, 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 plays a critical role and responsibility in the space sector, however, particularly regarding risk management and acceptance, 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 bottom-up approach.

There are many methods by which an organization might develop such a strategic approach. **Figure 5** provides one example. This construct is grounded in the key elements of any strategic plan: a focus on an organization's leadership philosophy; the development of a strong, compelling, and clear vision; and a set of guiding principles. The entire organization can then anchor its day-to-day mission execution decisions to this foundational understanding. A strategic plan with these elements is then the basis for development of the tactical plans of action and policies required to achieve overall goals and major aims. The strategic plan can also inform organizational design, including the structure, systems, processes, workforce competencies, and infrastructure by which the Agency will execute its mission and mitigate risk.

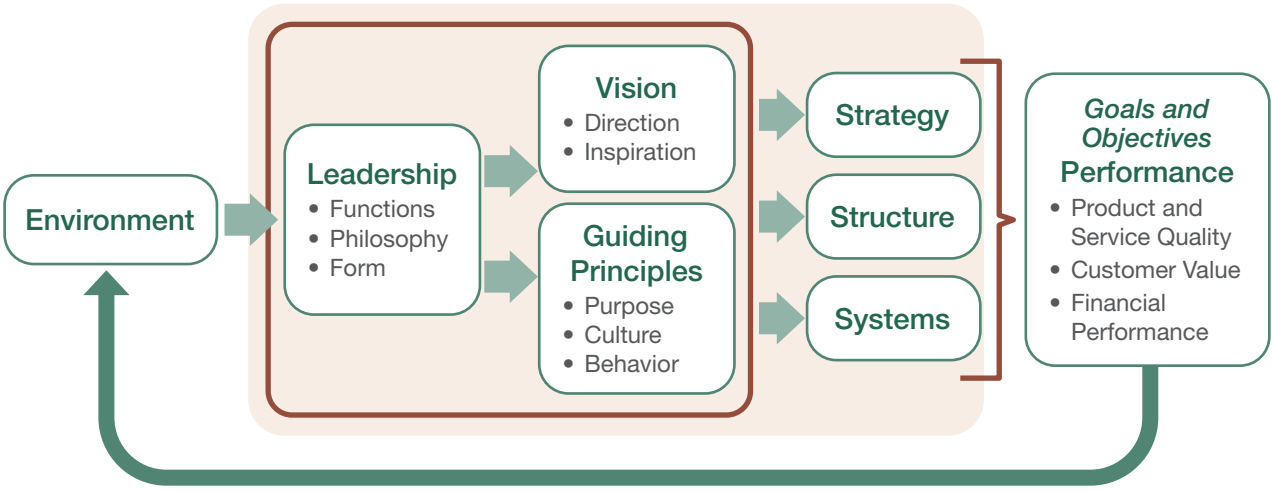

FIGURE 5. A Strategic Organizational Leadership Construct

The imperative for NASA to develop a strategic focus was at the heart of the ASAP 2020 Annual Report. In that report, the Panel asked NASA to consider a set of important strategic considerations described in Section II D, above. Regardless of what strategic organizational leadership construct NASA chooses to use, these critical questions implicate three main strategic elements that NASA must consider as it sets the Agency's agenda: Vision, Leadership, and Guiding Principles. For each element, a set of guiding questions, noted below, can stimulate thinking as NASA works to define its role in the coming decades. Armed with answers to these questions in light of the seven critical strategic considerations, NASA can begin to set its path. The guiding questions by element include, but are not limited to, the following:

Leadership (Functions, Philosophy, Form)

- What are the key organizational attributes NASA will adopt to align and execute its strategic plan (collaboration, transparency, consensus, and with whom)?
- How will NASA interact with both commercial and international partners?
- What organizing constructs will NASA use to execute its approach?
- How will NASA get buy-in with its centers and external stakeholders?
- How will NASA create accountability to the strategic vision and plan?

Vision (Direction, Inspiration)

- What roles does NASA intend to perform going forward through Mars exploration and why?
- How will NASA fulfill the needs of the nation and the taxpayers?
- How will NASA be a leader, not a competitor, in the space market of the future?
- Who are NASA's key stakeholders today and into the future?
- What does the NASA workforce of the future look like and how will it be achieved?
- What government and commercial infrastructure is necessary to fulfill this vision and how will this be acquired?

Guiding Principles (Purpose, Culture, Behavior)

- What are the inherent governmental functions for a national human space flight program that NASA must preserve?
- How will expectations be communicated to partners and to the workforce?
- What management practices will be employed?
- How will effective Systems Engineering and Integration (SE&I) be accomplished?
- How is risk managed and accepted? How will the Agency address shared risks, and under what conditions?
- What are the inherent governmental functions for a national human space flight program that NASA must preserve?

There are many examples from across the whole of government, and even at NASA, where the answers to the above questions have created a strategic plan that was then successfully implemented. At NASA, the Apollo program, the conversion of NASA's Kennedy Space Center to a multi-user spaceport, and the transformation of the NASA Mission Control Management Team are instances where a clearly articulated vision and guiding principles, wrapped in a thoughtful strategy, promoted change management, and resulted in the successful execution of complex projects. In the Department of Defense (DoD), the Navy Aegis Surface Combatant Program with its enduring five cornerstones of capability and the 2018 DoD National Defense Strategy also serve as examples where vision and strategic thought drove change and culture in mission execution.

We recognize that, like any government or private organization, NASA is constrained by resources, which shapes the extent to which it can respond to strategic imperatives. NASA's salient internal cost drivers are its workforce and infrastructure. Both encumber budget to maintain current staffing and systems and equipment, regardless of the program-specific work they do. Kept static, or flat, the same number of employees and pieces of equipment cost progressively more as prices escalate with inflation. These annually increasing costs then may consume more and more of the Agency's budget if not deliberately managed—eventually crowding out the resources that could otherwise be applied to alternate strategies, new programs, and innovations. Moreover, once resource commitments are made, such alternatives become much more difficult to pursue. Any effort to initiate new projects or programs risks falling victim to suboptimal approaches focused on immediate needs. Some risks are tolerated that might have been managed differently and more effectively if resources were less constrained. Eventually these short-sighted solutions become entrenched. The momentum of existing projects and the constant juggling of resources become barriers to change even when team members recognize, "if we had it to do over, we wouldn't do it this way." Adding resources can help relieve this condition, but solutions can also be found in a careful strategic effort to align priorities from the top-down and to manage the enterprise more efficiently, thus freeing existing resources for alternate strategies, new programs, and innovations.

Whether "right sizing" for efficiencies, shifting out of more ubiquitous capabilities and into more NASA-unique work, or simply freeing resources for innovation, technology development, and programmatic content, evolving the workforce is facilitated first by this same deliberate alignment. The alternative leaves the Agency in the difficult situation where the cost of just being in business consumes a growing fraction of NASA's resources, at the same time the Agency is being asked to take on more and increasingly complex missions, leaving it with fewer options to manage cost, schedule, and technical risks.

Finally, culture is a key dimension of the context within which a strategic vision is framed, and that matures and evolves along with changing roles and responsibilities in the Agency. We remind NASA that a hallmark of any organization with a "generative," or highly evolved safety culture is that there is, or should be, a chronic unease about safety. This unease, no matter how smoothly or successfully programs appear to be functioning, is what provides a hedge against complacency. The Panel does observe this unease, at times, during some discussions with NASA management. It is not observed consistently across all programs, with all providers, or with all levels of management, however. Over the coming year, the Panel will continue to ask questions in the vein of "what keeps you up at night," and will regard forthright answers to these questions as an indication that NASA's safety culture is maturing in an appropriate manner.

In sum, over the past several years, the ASAP has observed the development and maturation of various plans, structures, and processes, and these continue to shape the Agency's ability to identify, accept, and mitigate risk. It is not yet evident, however, how these disparate efforts are aligned with and undergirded by a strong understanding of a top-down view of the agency's purpose, vision,

and guiding principles, especially as the organization moves into a future space sector growing ever more dynamic and complex. In fact, as the Panel has reviewed various programs, projects, and initiatives, issues symptomatic of a misalignment or absence of a broader cohesive strategic approach have emerged. This leads us to make the following recommendation:

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

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.

Commercial Low-Earth Orbit

Overview

NASA's program to commercialize LEO provides a specific case study for the application of the principles described in Section III, albeit on a smaller scale than the Agency-wide strategy we advocate in this report. In the mid-2000s, when NASA established the Commercial Resupply Services (CRS) program, the Agency took the first step to open the aperture of space activities to private interests, and to start facilitating the growth of a new economic sphere—pursuits in space spurred by market forces instead of sole reliance on government funding. Since then, NASA has repeated that model with the Commercial Crew Program (CCP), and it is now looking at how to incorporate the same approach into the Artemis campaign. As NASA looks to expand its activities to cis-lunar space, the Agency expressed a desire to help "commercialize LEO" and thereafter instituted a series of tactical actions targeted at achieving that aim.

Will NASA require specific engineering or operational skills to achieve its goals? Will it require a workforce with a deeper understanding of the acquisition processes and how to shape contracts for better risk management? As NASA looks to the future, what workforce does the Agency want to have? What will be the Agency's enduring role in the effort to commercialize LEO?

ASAP's Observations

The ASAP has not been able to discern the overarching strategy, goals, and outcomes NASA is trying to achieve with the LEO commercialization effort, however. Applying a strategic approach to the LEO commercialization program, the Panel urges NASA to address the following questions:

"What is NASA's role in helping to create a commercial market in space and why is that role uniquely NASA's?" The term "commercialize LEO" can mean different things to different people. Generally, though, the agenda concerns stimulating private investment in new exploration capabilities. While NASA is unique across all government agencies in its knowledge of the space environment, there are other branches of government better suited to molding and expanding the U.S. economy. Thus, NASA needs to clearly articulate what outcomes it seeks to achieve. In addition, creating an entirely new economic sphere will likely take a whole-of-government approach, raising questions about how and when NASA will bring talents and skills from other government entities to bear. A clear set of goals and outcomes will help shape the overall necessary approach, providing clarity for other agencies on possible roles.

"How will the Agency interact with both commercial and international partners?" In the context of the goals the Agency has identified, what sectors and types of companies will NASA need to engage and how will they engage? Will there be a need to reach out to non-traditional sectors? How do the Agency's targeted outcomes intersect with international interests, both for current partners and emerging space nations?

"How will the Agency address shared risks?" One clear Agency goal the Panel understands is NASA's desire to have a privately built and operated space station on orbit prior to the decommissioning of the ISS, allowing government-sponsored research and technology development to seamlessly continue in LEO. Shared risk management and workforce strategies are lacking, however. How, for example, will NASA ensure that human platforms provided by commercial providers are safe for NASA personnel? What is the risk profile NASA is willing to adopt to achieve desired outcomes? Additionally, it is unclear to the Panel what the anticipated outcome is for the Private Astronaut Missions project or how that activity fits into a larger strategy that advances the goal of establishing privately operated research platforms or other intended outcomes. Thus, it is hard to discern how NASA assesses the risks and rewards of sending private citizens to the space station. Finally, to be successful in achieving whatever outcomes the Agency targets, an honest and comprehensive strategically derived budget needs to be defined.

"What management practices will be employed?" and **"How will the expectations be communicated to its partners and to its workforce?"** What acquisition and partnering mechanisms are available to achieve the outcomes NASA identifies? What metrics will be used to determine if NASA's goals are being met?

"How will effective Systems Engineering and Integration be accomplished?" The SE&I mechanism NASA chooses to employ should be sufficient for the Agency to proactively understand and manage risk within the risk profile the Agency thinks is acceptable to achieve intended outcomes.

"What should the NASA workforce of the future look like and how will it be achieved?" Will NASA require specific engineering or operational skills to achieve its goals? Will it require a workforce with a deeper understanding of the acquisition processes and how to shape contracts for better risk management? As NASA looks to the future, what workforce does the Agency want to have? What will be the Agency's enduring role in the effort to commercialize LEO?

IV. Agency Governance

The Panel sees direct links between executive expectations, governance approaches, leadership team performance, and risk management. As an agency with a long record of high-performing teams who manage the still-incredible risks associated with human space flight, we intend the following recommendation to help NASA's executive leadership team leverage that same level of performance in formulating and executing its critical portfolio of current and future missions.

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

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.

Though 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 Headquarters staff and the Center Directors would comprise an Agency steering committee with a deliberate Agency-level focus, rather than as representatives from and advocates for their areas of responsibility or field centers.

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

equipment—an explicit shift to an Agency-level focus is an essential start to reducing fixed costs and freeing more resources for new work in space exploration.

To maximize their leadership team's performance, NASA executives will need to operate as a deliberately crafted high-trust team—a team that rests on shared competence and credibility to confront reality collaboratively. One source of insight for how NASA could improve trust within its executive team is Stephen M.R. Covey's The Speed of Trust in which he presents a simple inventory of behaviors that are prevalent in low- and high-trust organizations, as shown in **Table 1**.

TABLE 1. Cultural Behaviors in Low and High Trust Organizations
(Source: *The Speed of Trust: The One Thing That Changes Everything*;
Stephen M.R. Covey, shared with permission and all rights reserved by Franklin Covey)

Low-Trust Organizations	High-Trust Organizations
People manipulate or distort facts	There is real communication and real collaboration
People withhold and hoard information	Information is shared openly
Getting the credit is very important	People share credit abundantly
People spin the truth to their advantage	People are candid and authentic
New ideas are openly resisted and stifled	The culture is innovative and creative
Mistakes are covered up or covered over	Mistakes are tolerated and encouraged as a way of learning
Most people are involved in a blame game, bad-mouthing others	People are loyal to those who are absent
There are numerous "meetings after the meetings"	There are few "meetings after meetings"
There are many "undiscussables"	Transparency is a practiced value
People tend to overpromise and underdeliver	There is a high degree of accountability
There are a lot of violated expectations, for which people try to make excuses	
People pretend bad things aren't happening or are in denial	People talk straight and confront real issues
The energy level is low	There is a palpable vitality and energy–people can feel the positive momentum
People often feel unproductive tension–sometimes even fear	

As the "Board of Directors" works to eliminate low-trust behaviors in favor of high-trust behaviors, intra-team communication will become more transparent. And, as they engage from an Agency-perspective in this team environment, they are able to pool the insights and expertise from their areas of responsibility and their individual experience on behalf of the full team and achieving more

effective strategic-level outcomes becomes possible. In this way, the "Board" can be more deliberately aligned in their role as NASA's guiding coalition, engaging in all Agency-level strategic decision-making, not to serve parochial single-center needs, but to set a top-down sense of purpose and priorities, which then influence Agency and Center strategies and actions.

Specifically, such alignment enables leaders to identify and relinquish legacy paradigms that do not serve future needs, articulate program objectives and risk management expectations, realign and optimize human capital and infrastructure, and invest in new missions and the capabilities that best serve them. Importantly, however, transparent communication and high-trust levels cannot be left to good intentions. For transparence and trust to characterize leadership team engagement, Center Directors and other "Board" members should be incentivized and selected for demonstrating and fostering these behaviors in their daily work.

Finally, for this model to have greatest impact, transparent communication within the "Board of Directors" must propagate down each principal's management lines, enabling the full management team and workforce across NASA to both understand and deliberate a common set of challenges, opportunities, and choices. This both aligns NASA's workforce in support of Agency priorities and facilitates feedback to the "Board" that can further improve effectiveness.

V. Program Management Across the NASA Enterprise

As a global leader in human spaceflight, NASA has had tremendous successes throughout its history, and much of that success has stemmed from strategic, coherent program management, expert leadership, and clarity of purpose and process from the top down. As with many of this nation's most successful strategic efforts, NASA placed priority on program management approaches that valued clear lines of authority, a coherent resource management approach, and a transparent yet comprehensive roadmap for integrated risk management. For reasons stated previously in this report, however, 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 programs and projects that collectively contribute to the objectives of Artemis will be brought together as a cohesive campaign, and the Panel now notes several deviations from NASA's history that give cause for 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.**

As we've noted, the EGS, Orion, and the SLS were set up as three individual programs, each with their own processes and structures—rather than what previously would have been an integrated single program. Ordinarily, the resulting critical gap in systems integration would have been filled by a single

overarching program. Since this does not exist, the Agency is attempting to manage the systemic risks of the Artemis enterprise in the structure they have adopted without deliberately assessing whether that structure is best suited for the necessary purposes of broad integration and enterprise risk management. Specifically, at this point, the Artemis campaign is not established formally as an "Artemis program"—there is no designated Program Manager who has program management authority over all aspects of Artemis developments across the enterprise. Although NASA used a well-developed program management structure for the Apollo, Space Shuttle, and ISS programs of the past, there is no similar unifying and comprehensively aligned program framework for the Artemis enterprise. In other words, there is no clearly defined leader of the enterprise, transparently endowed with the ultimate authority, responsibility, and accountability to direct all Artemis-related programs and ensure full synchronization and integration of effort (see **Figure 6**).

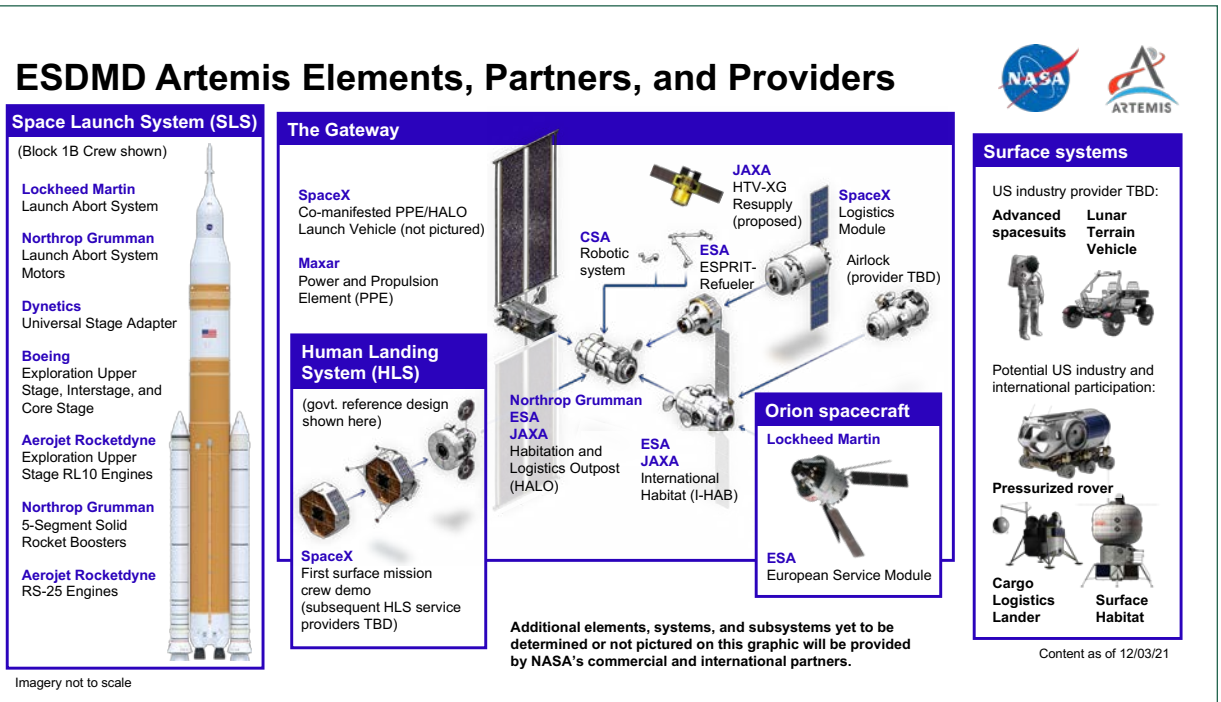

FIGURE 6. Complexity of Artemis—Commercial and International Components

Instead, NASA has undertaken a number of new integrating efforts in an attempt to fill the void. There is an integrating manager who has created various processes that primarily rely on a broad series of boards and panels to perform a "bottoms-up" review process, designed to raise issues and resolve integration questions as they arise through day-to-day program work. The sheer number of programmatic efforts within the enterprise make it unclear whether the critical integrated risk management outcomes are fulfilled by this approach, however. In particular, the ASAP is concerned about the heavy reliance on lower-level workers to raise integration concerns across sub-programs. Without a

comprehensive and accountable approach to integrated risk management from the enterprise level, the workforce responds to a large bureaucracy of panels and boards, without authoritative guiding principles (e.g., an Artemis Systems Engineering and Integration Plan) and transparent direction on roles, responsibilities, and authorities for sub-program risk integration. As key resource decisions that may affect integrated risk are made, it is unclear who is accountable—who specifically is accepting that risk.

Although NASA has no Artemis program, nor a Program Manager, NASA markets the Artemis effort as a "program" in its Artemis Plan, available on NASA's website: (*https://www.nasa.gov/sites/default/files/atoms/files/artemis_plan-20200921.pdf*). The use of the word "program" to describe this human endeavor makes sense, given NASA's history. The term "program" signals adherence to a shared body knowledge and experience about how integrated program management flows from an accountable program manager at the top who strategically directs all programmatic interconnections across the defined enterprises. Given NASA's historical culture of using this top-level program as an organizing framework for highly complex human space flight campaigns, NASA's use of the phrase "Artemis program" without actually employing a program of architecture risks is confusing both employees and contractors about who is ultimately responsible and accountable. Ensuring that NASA employees clearly understand roles, responsibilities, and authorities surrounding the Artemis enterprise has been an ongoing concern, and leads the Panel to the following recommendation:

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

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.

2. There is no Artemis prime integrating contractor in support of the NASA workforce.

Artemis is by far the most complicated human space flight endeavor that NASA has ever attempted. Sub-programs across the entire Agency, along with international partners, and contractual arrangements for highly complex services such as the Human Lander System (HLS) are spread across multiple centers and encompass countless SE&I points across the enterprise. In the past, NASA has heavily leveraged a single integrating contractor who works across all elements of the system (e.g., USA for the Space Shuttle program and Boeing for the ISS program) to perform the critical aspects of managing the SE&I across sub-programs and projects, and to ensure there is consistency of standards, practices, and development outcomes for NASA's human space flight programs. At this point in the Artemis campaign, each sub-program has designated its own integrating contractor, and there is no support contractor who has the "whole picture view" of how the entire campaign must come together with consistent risk management approaches. It is unclear how much NASA may be paying for duplication

of effort across programs, projects, and centers, or whether the work myriad integrating contractors perform is consistent or in conflict. Since a Prime Integrating Contractor has often been responsible for risk management integration throughout development in previous programs, the Panel advises NASA to gain clarity on how this deviation from previous program practices is achieving equivalent risk management outcomes.

3. An unprecedented mix of acquisition approaches presents risk management challenges. Best practice dictates that an acquisition "life cycle" should encompass transparent and unambiguous authorities, responsibilities, and a chain of accountability for the entire development cycle, across all entities participating in the development. Contractual instruments should then clarify these authorities and responsibilities. An overarching blueprint for acquisition, oversight requirements, and insight should thus be aligned to a well-defined, comprehensive NASA risk management strategy and promulgated to all contracts in such a way as to ensure that overall integrated risk management—from project-to-project, program-to-program, and mission-to-mission—is clear, consistent, and coherent. Every acquisition, whether a contractor supporting a NASA in-house program such as SLS, or a "service contract" such as HLS, should have a consistent, unambiguous approach to risk management that spans the entire enterprise. Beyond this, the public's trust in NASA as the Nation's steward of human space flight demands that the Agency ensure accountability for risk management is very clear.

In this context, NASA has settled on a broad mixture of acquisition approaches to achieve the outcomes of the Artemis campaign, but it is unclear whether these contracts are synchronized to ensure responsibilities are consistently explained, authorities are cogently defined, and accountabilities are applicable for a highly complex, SE&I context.

As an example of the challenges NASA faces in this regard, the night landing of the SpaceX Crew-1 (see **Figure 7**), though successful, revealed a concerning dissonance. The Panel learned from discussions with CCP management earlier this year that prior to the landing, NASA and SpaceX had differed in their understanding of the level of risk to be incurred, and that last-minute communications had been necessary to ensure NASA approved the plans for the night landing. NASA had understood prior to the mission that a daytime landing was the lowest risk option. SpaceX understood that a night landing was within design ratings, and furthermore, weather conditions and sea states at night are often better for landing. In this case, the conditions on the night of the landing were optimal, but according to weather forecasts at the time, the daytime sea state conditions would likely have introduced unnecessary hazards. Last-minute communications and decisions made under these circumstances could have resulted in a poor decision, due to immense operational pressures. NASA and SpaceX should have had a common understanding of relative risk levels and of the lines of communication and authority well before the mission—and certainly before a last-minute NASA approval was needed for the landing plans.

As another example, Boeing began 2021 having just begun to implement the recommendations of the Joint Independent Review Team (JIRT), which was established following the anomalous first

FIGURE 7. Crew-1 Night Landing

Orbital Flight Test (OFT-1) in December of 2019. By late 2021, all JIRT recommendations had been implemented. Improvements included changes to the software certification strategy. In July 2021, an FRR for a second uncrewed orbital flight test (OFT-2) was conducted, just days before the scheduled launch of OFT-2. Propulsion system issues with the Starliner—specifically, the troubleshooting that was necessary when several propulsion system valves were determined to have been in the wrong position—caused an indefinite delay. The Panel's concern is that during the OFT-2 Flight Readiness Review (FRR), NASA and Boeing differed in how they characterized the risk that was brought to light by the stuck propulsion valves. Boeing's risk posture, communicated as "low," was related to its contractual requirements, while the NASA team evaluated the risk, communicated as "moderate," in a broader mission context. While the ultimate decision was to troubleshoot the stuck valves, the FRR revealed NASA and Boeing do not share a common understanding of how to assess and characterize risk. Equally disturbing was that the program got very close to launching the spacecraft before the stuck-valve issue was identified. This is exactly the type of situation that the Panel urges NASA to aggressively avoid as the Agency proceeds with assigning Artemis contracts.

The Panel strongly advises that NASA ensure the guiding principles of inherent governmental functions are clearly articulated, and through a centrally managed contracts strategy, acquisitions are clearly aligned to an overall risk management strategy and a clear framework for each contractual approach. NASA appears to be buying some high-risk capabilities, such as the HLS, as a "service," but it must nonetheless ensure that those inherent governmental functions related to risk management and safety of flight are clearly specified in contracts, and that the custody of accountability remains transparent and enforceable. As necessary, NASA systems engineers should be explicitly assigned contractual duties that fit their required responsibilities.

4. Regardless of whether a partner-approach or an acquisition-approach is used, consistent expectations of transparency and data-driven risk discussions are required.

The Panel continues to be concerned about cracks discovered in the hull of the ISS service module transfer tunnel that manifested as an increased leak rate in 2019. In early 2021, two cracks in the pressure shell were repaired, which reduced the leak rate but did not fully mitigate it. Now, two years after the cracks were initially discovered, the investigation of root cause(s) continues. The Panel continues to follow this issue closely, both through updates on the root cause investigations and the operational procedures established to manage the risk. Likewise, the Russian Multipurpose Laboratory Module (MLM) also has the Panel's attention. The MLM experienced in-flight anomalies on the day of launch. The Russian team worked around these anomalies, but when the MLM docked eight days later, it experienced more anomalies during the post-contact steps during docking. Each of these anomalies represents the fundamental risks the ISS program must continue to manage; problems attributable to an aging station and human errors that can lead to unsafe operations.

To minimize anomalies, and mitigate their impact when they do occur, requires transparency between partners and private industry. NASA must set the expectation and standards for transparency and data-driven discussions required for operating in the more high-risk missions of the future. Of special importance is that these discussions take place in a proactive pre-crisis environment, not solely in reaction to a dynamically evolving crisis. Moreover, the ISS program must continue to be vigilant and drive investigations that uncover root cause(s) and effects for all anomalies to ensure the equipment is continuing to perform as expected, and that the operational community maintains its knowledge and training at the required levels to safely operate the space station. The same standards must apply to all partners and private companies that are involved in NASA missions, regardless of contract structure or partner type.

VI. Congressional Actions

For several years, the Panel has expressed concern with the risk orbital debris poses to orbiting spacecraft and transiting astronauts. The hazard from orbital debris has been recognized as a major issue in every program. It 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 ISS. NASA declared it an Enterprise Risk in 2017. The ISS has been maneuvered over two dozen times since its inception to avoid collision with orbital debris, and such maneuvers now seem necessary even more often.

Space has become more congested, and the problem of orbital debris in space is growing at a concerning pace. CubeSats and other small satellites are being launched more frequently, 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 on-board maneuvers with very short turnaround times, increasing the difficulty of tracking and planning for collision avoidance. On a global level, across the full international inventory, several close calls occur weekly between numerous space objects, many of which are not capable of maneuvering out of harm's way. The debris issue recently took a sudden turn for the worse in November of 2021, when a Russian anti-satellite test destroyed the Russian Kosmos 1408 satellite and significantly contributed to the debris field near the altitudes of the ISS.

The risks to the space environment and to all who use it must now be actively managed on a continuous basis, with robust tracking sensors, timely data, high-precision predictive algorithms, and—similar to air traffic control—a tight network between those who track and those who are tracked, to ensure appropriate warnings are disseminated, acknowledged, and if possible, acted upon to avert catastrophe. The national approach to this issue has not been fundamentally revised in many years, leading to archaic methods and analyses, and incoherence among numerous autonomous tracking services. While the ASAP is principally focused on the serious hazards to NASA spacecraft and astronauts, the Panel recognizes this issue must be tackled on a broad front. In our 2017 Annual Report, we warned that "the U.S. government should seriously consider implementing significant improvements for Space Situational Awareness analyses and the provision of Space Traffic Management services, as well as expand its efforts in developing international strategies to reduce orbital debris generation in the future." The Panel further asserted it was important for "the U.S. to take a leadership role and for the National Space Council to address" the risk, and that the Panel believed "a lead Agency in the U.S. should be assigned to spearhead and coordinate efforts to prevent the generation of new debris and reduce hazards posed by existing debris."

The Panel continues to be concerned that Congress and the Administration have not yet reached an agreement on the necessary actions required to address this issue, rendering the U.S. government, industry and research partners, and international stakeholders unable to move forward in a fully coherent manner to materially reduce orbital debris risks and to increase the sustainability of space as a global strategic domain. It is well overdue for the U.S. to exert effective international leadership in the

safety of space operations by 1) designating and funding a Lead Agency to provide timely and actionable safety data to all space operators; 2) working proactively within government, with industry, and in partnership with the international community to develop standards, guidelines, best practices, and "rules of the road" for safe space operations; and 3) supporting 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.

In the Annual Report for 2020, the Panel outlined the actions needed by Congress:

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

The Panel recommends the following for 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.

In summary, the Panel continues to contend that the issue of orbital debris not only presents a standing safety concern for NASA, and commercial providers, especially for human-tended spacecraft, but it is also a growing threat to the sustainability of space as a peaceful domain for science, exploration, innovation, and commerce. It is the Panel's hope that comprehensive actions are soon taken by Congress—and by NASA in support—to advance risk reduction in a strategic and coherent manner.

Additionally, as far back as 2015, the ASAP noted that the specific language in the NASA Authorization Act of 2005 concerning Human Space Flight Independent Investigations, while perhaps appropriate and logical for the ISS and Space Shuttle, was inadequate and obsolete for the emerging environment that included reusable and commercially provided space vehicles. In 2015, the ASAP made the following recommendation:

2015-05-02: Human Space Flight Mishap Response Procedure

The 2005 Authorization language should be reviewed with today's systems in mind…including details on 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 oversight is required. The mishap response procedures should be thought through, documented, and in place well before any actual flights.

The 2005 Authorization language is even more inadequate when considering the emerging space travel involving non-NASA participants. Yet this recommendation remains open and increasingly relevant.

VII. Forward Work

As the Agency proceeds with caution in accordance with White House and Centers for Disease Control guidance, the ASAP anticipates conducting its 2022 program of work with in-person insight, fact-finding, and quarterly meetings. Much of our focus will remain on the strategic issues we have discussed in this report. In addition, we intend to delve more deeply into specific safety and risk management issues of Artemis as a whole, its components—especially the HLS and the extravehicular mobility units—and the requisite integration. We will continue to probe the ongoing CCP and the progress of Starliner, the health and safe operation of the ISS—with plans for maintaining a secure location for risk reduction efforts in LEO—including the LEO commercialization approaches, and the Artemis I and II progress.

A new item on our plate will be to look at the emerging potential for expanded opportunities for a wider variety of individuals to visit space. While it is tempting to compare this to the growth of commercial aviation nearly a century ago, there are very important differences. The physiologic stresses of space flight are more significant than those experienced by passengers in atmospheric flight. Medical or behavioral health events onboard a spacecraft also pose more significant challenges to address than those same events occurring during commercial atmospheric flight. Passengers in spacecraft are an intimate part of the operational environment, and any medical or behavioral event that occurs can have a profound impact on crew operations, as well as on crew and mission safety. NASA and international partner medical authorities—with decades of experience in space medical certification and mission medical management—are in a unique position to support the commercial space flight industry in enabling more people to safely experience space flight. NASA and the ISS medical systems continue to facilitate and support tourist visits to the ISS, building an important health and medical experience base.

The European Space Agency announced the Para Astronaut Feasibility Project early in 2021, which invited application to their astronaut program for people who have met all qualifications required to become an astronaut, as well as for people with certain lower-limb deficiencies and persons of short stature. In January 2021, President Biden signed an Executive Order on Preventing and Combating Discrimination on the Basis of Gender Identity or Sexual Orientation. NASA medical authorities continue working to determine how medical standards can be adjusted to broaden opportunities for people with certain disabilities. The Panel will follow the developing health and medical support for more people to fly in space with great interest from a safety perspective.

VIII. Conclusion

The space sector, both domestically and internationally, is rapidly transforming. More nations are engaged in space activities than at any point in history, and private industry is recognizing the economic value of the space domain. Sixty years of NASA's efforts and U.S. government investments have been instrumental in the establishment of the foundational knowledge leveraged by the world. As NASA looks to the future and moves to expand human knowledge and operational capabilities beyond LEO, it must recognize and adapt to the new environment and decide strategically how to forge humanity's path outward while managing the risks in an appropriate manner.

APPENDIX A

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

2021 Recommendations[1]

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.

1 *Note on colors:* Red highlights what the ASAP considers to be a long-standing concern or an issue that has not yet been adequately addressed, or 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.

- 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.

OPEN NASA's response not provided at time of ASAP Annual Report 2021 printing.

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—i.e., protecting budget, preserving the workforce configuration, maintaining every building and piece of major equipment—an explicit shift to an Agency-level focus is an essential start to reducing fixed costs and freeing more resources for new work in space exploration.

OPEN NASA's response not provided at time of ASAP Annual Report 2021 printing.

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 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 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.

Rationale: As with many of this nation's most successful strategic efforts, NASA placed priority on program management approaches that valued clear lines of authority, a coherent resource management approach, and a transparent yet comprehensive roadmap for integrated risk management. NASA has deviated from previous program management "best practices" that have been hallmarks of successful strategic programs. The Agency is attempting to manage the systemic risks of the Artemis enterprise in the structure they have adopted for Exploration Ground Systems, Orion, and the Space Launch System, without deliberately assessing whether that structure is best suited for the necessary purposes of broad integration and enterprise risk management. Concerns involving the absence of 1) a designated Program Manager with program management authority over all aspects of Artemis developments across the enterprise; 2) a designated Prime Integrating Contractor responsible for risk management integration; and 3) a congruent acquisition life-cycle approach suitable to ensure an overarching blueprint for acquisition, oversight requirements, and insight have prompted the Panel to advise NASA to gain clarity on how this deviation from previous program practices is achieving equivalent risk management outcomes.

OPEN NASA's response not provided at time of ASAP Annual Report 2021 printing

Open Recommendations from Prior Years

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 20 missions in low-Earth orbit, and the Agency definitely 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 of 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 front.

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

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

OPEN 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.

2020-03-02 Designation of a Lead Federal Agency for Civil Space Traffic Management (NASA)

Finding: For several years, the Panel has expressed concern with the risk of damage to orbiting spacecraft and transiting astronauts due to micro-meteoroids and orbital debris (MMOD). The hazard from MMOD has been recognized as a major issue in every program. MMOD is the dominant contributor to the calculations of loss-of-crew 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 NASA:

- Support and partner with the Lead Federal Agency once one is selected.
- In the interim period:
  - Because of the direct relationship to astronaut and spacecraft safety, ensure that risks having to do with MMOD, Space Situational Awareness, and Space Traffic Management are addressed in NASA's ongoing activities and in future budget requests.
  - In collaboration with other government agencies and industry, develop and publish guidelines for Space Traffic Management focused on current and emerging challenges to maintain the safety of astronauts and spacecraft.
  - Develop a proposal for a Space Traffic Management technology roadmap.

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.

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

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

OPEN NASA concurred on 12/17/20 with the recommendation to support and partner with the lead Federal agency for Space Traffic Management once one is selected. NASA is taking steps in the interim to address the ASAP recommendation. Regarding astronaut and spacecraft safety, through the leadership of the Office of Safety and Mission Assurance (OSMA), NASA continues investing in characterizing and managing risks to spacecraft and astronauts from MMOD. Regarding development of guidelines for Space Traffic Management, the NASA Office of Chief Engineer (OCE) has developed two documents in support of the ASAP recommendation. One document serves to capture best practices for ensuring safe space operations with respect to collision avoidance, and the other document ensures future NASA missions continue to plan for and implement collision avoidance practices. Future updates will permit aligning the best practices with emerging space traffic management guidance by the selected lead agency. OSMA and OCE are also working with the Space Technology Mission Directorate to outline a proposal for a Space Traffic Management-related technology roadmap, focused on gaps that are not being otherwise addressed. The ASAP will continue to review the Space Traffic Management technology roadmap and awaits the Congressional designation a Lead Federal Agency before closing this recommendation.

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 next-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..

OPEN NASA responded on 9/11/19, concurring with the recommendation. While NASA has presented plans for the development of the xEMU, including flying a prototype xEMU on the ISS for testing, the xEMU development and acquisition approach is primarily focused on producing suits for the lunar campaign. The Panel has not received sufficient information indicating how the current approach to xEMU development and acquisition will mitigate the ongoing risks of extending the current EMUs on ISS to 2028.

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 (CCP) 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 fairly 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.

Rationale: Despite a desire to launch the uncrewed test flights (Demo-1 and OFT) as soon as feasible, it is important to keep in mind that the primary purpose of those flights is to fly the vehicles in a configuration as close as possible to the first crewed flights in order to reduce risk. If content important to that purpose is not flown in a test that essentially duplicates the conditions of the first crewed flights, uncertainty is increased, and safety could be compromised.

OPEN NASA originally responded on 3/29/19, concurring with the recommendation. NASA continues to work with the commercial providers to obtain valuable data from both crewed and uncrewed test flights in order to minimize risk and correct any emerging issues. The results from the series of reviews for each flight will culminate in a Certificate of Flight Readiness, asserting that the commercial provider has completed all work associated with meeting the applicable requirements, standards (including alternate standards), and hazard reports. The final certification work for SpaceX has been completed and they have moved on to operational flights, just launching Crew-1 and Crew-2. The certification work continues with the Boeing system and should undergo the same rigorous process of reviewing the results of every flight to assure any issues are worked or corrected. Work will be ongoing into 2022 and beyond.

2018-04-02 Action to Ensure U.S. Access to the International Space Station Given Commercial Crew Program 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 International Space Station (ISS) in calendar year 2019. Currently, there are no Soyuz seats available for U.S. crew after 2019.

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

Rationale: Without CCP flights in 2019, the U.S. will have no other means of access to the ISS unless other options are identified and approved, or existing constraints are waived. Although they may not be needed, having back-up plans in place for such contingencies could be extremely important if the CCP flights are significantly delayed.

OPEN NASA responded on 3/29/19, concurring with the recommendation. NASA is developing options to protect the presence of American crew on the ISS to support the U.S. On-Orbit Segment. During the ASAP's 2020 Second Quarterly meeting, the Panel advised NASA to broaden its approach to this issue and resolve this recurring risk as part of normal practice and not on an increment-by-increment basis. Specifically, consider sustainable solutions in the event of continuing operations with reduced crew capacity that ensure that the critical crew skill sets are on board at all times. For example, manifesting every crew rotation flight, on either U.S. or Russian spacecraft, to have at least one U.S. and one Russian crewmember on board to facilitate this kind of "insurance."

2016-04-01 Asset Protection—Security Clearance Policy

Finding: NASA is taking a holistic approach to asset protection, linking space asset protection, cybersecurity, and critical infrastructure on the ground. The identification of James Leatherwood as Principal Advisor to the Associate Administrator and establishing an Enterprise Protection Program (EPP) modeled after the Technical Authorities is a positive step. The Panel was gratified to see that NASA is taking a holistic approach and starting down the path of putting in place the management policies and practices to have an effective EPP. While there are many challenges ahead, one of the big challenges to an effective program is having appropriate clearances for the appropriate people in the Agency who make the decisions to protect assets from threats. Currently, there are too many cases where security clearances are lacking. NASA has put in place a system to work around these difficulties, but it is not optimum.

Recommendation: NASA should make it a matter of policy that priority is given to obtaining the appropriate level of security clearance for all personnel essential to implementing the EPP, including the appropriate program managers.

Rationale: The appropriate people in the Agency need to have to have a level of clearance necessary to understand the threat, make the proper decisions, and allocate the proper resources. When a new program manager is coming online, if he or she does not have the appropriate security clearance already, submitting the necessary paperwork may not be high on the new manager's list of tasks. NASA needs a policy to put a high priority on the submission of appropriate clearance paperwork.

OPEN NASA responded on 1/17/17, concurring with the recommendation. In 2019, NASA established clearance requirements within the governance management system of the EPP and reviewed positions, descriptions, and compliances. In early 2020, the Panel requested a summary of the outcomes of this advertised process—specifically, a NASA-wide list of program managers' job descriptions and their current security clearance requirements/status. The Panel will then be able to ascertain the effectiveness of the advertised process to assure that security clearances are appropriately distributed. It is hoped that the outcomes of the 2019 reviews generated appropriately adjusted security clearance requirements for key personnel who have technical authorities

and responsibilities, and are accountable for implementing EPP policies, directives, and threat information within their programs.

2015-05-02 Human Space Flight Mishap

Finding: The CCP is now developing a formal plan for how it will respond in the event of a major malfunction or mishap. In addition to optimizing what can be learned by proper investigation of malfunctions or mishaps, this plan must comply with 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 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.

OPEN NASA originally responded on 4/30/16, concurring with the recommendation. The response stated that NASA was reaching out to the Federal Aviation Administration 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 option 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 the Congress are still working to establish a satisfactory process to address the concerns previously articulated. The ASAP believes action is increasingly essential and urgent as NASA has already begun launching astronauts on commercially provided vehicles, and the future Artemis missions will be even more complex in their involvement of commercial providers and international partners.

APPENDIX B

Closure Rationale for Recommendations Closed in 2021

2021-01-01 Design a Top-Level Plan for the Size and Composition of the NASA Workforce and Infrastructure

Finding: NASA has stated that the size and composition of the NASA workforce should be shaped by strategic guidance, rather than by independent hiring plans developed at the Center and organizational level. However, based on the information the Panel has received to date, it appears that key decisions related to workforce needs are being made tactically by individual Centers, rather than in collaboration with Headquarters, or in response to top-down guidance.

The NASA Human Capital Office has also developed a number of principles intended to guide its workforce management efforts, such as "NASA's total workforce is agile and mission-driven, not supply-driven in all workforce segments." Although that may be the ultimate goal, it does not appear to be an accurate assessment of the current situation, and the Panel is not aware of a coordinated strategy to achieve such a state of affairs.

Depending on how NASA answers the questions regarding its role and workforce, they have an opportunity to align their infrastructure to their long-term strategy. That is, by taking a top-down approach to align all Centers to Agency priorities, they should identify and close facilities that are not critical to Agency programs. This will contribute directly to reducing fixed costs and freeing resources for NASA's programs.

Recommendation: NASA should develop a top-level plan for the size and composition of its workforce and its infrastructure that takes into account its aspirations for future missions, innovation and technology development, and potential partnerships with industry, academia, and the international community. The plan should be developed in coordination with the Centers and should clearly articulate roles and responsibilities for maintaining the necessary expertise and experience. The plan should also be communicated with key stakeholders and updated on a regular basis.

Rationale: The existence of a skilled and experienced workforce has always been critical for NASA to safely accomplish its mission. Because of rapid changes in technology and an increased reliance on commercial and international partners, it is more important than ever for NASA to think strategically about its future workforce and infrastructure needs. Such an effort will be challenging, and it will certainly take time to complete; however, because it will likely have significant and immediate benefits, it should be initiated as soon as possible.

NASA's Response: NASA responded on 6/14/21 by concurring with the recommendation to develop a top-level plan for workforce and infrastructure. NASA stated that such plans are currently underway with a progression of steps. These plans are deleted for workforce, with the Office of Chief Human Capital Officer leading the development; and for infrastructure, with the Office of Strategic Infrastructure leading the development. NASA agrees with the ASAP's opinion that "such an effort will be challenging, and it will certainly take time to complete." Given the scope of the effort, this NASA response did not commit to a delivery date, however, leadership was amenable to providing periodic briefings to the ASAP to assess progress. This recommendation is superseded by Recommendation 2021-05-01.

2018-02-01 NASA Safety Assurance Process Scope and Quality (2017-02-01 REVISED)

Finding: In visiting the Centers and the NASA Safety Center (NSC), the Panel found some deficiencies in the audit system—such as system safety—where it became apparent that the workforce was not adhering to policies and procedures, or that policies and procedures were not well understood. While in some cases there was integrity and audit processes, in other areas the NSC did not appear to be auditing at all or they audited infrequently.

The Panel is comfortable that the Office of Safety and Mission Assurance (OSMA) has established, prioritized, and implemented a schedule and periodicity cycle for Center-level safety audits. However, the Panel wants assurance that the OSMA has a mechanism in place to verify that the NASA safety policies, processes, and procedures are being followed to ensure effective employee safety, system safety, and program safety. Effective safety assurance involves in-depth assessments of safety culture and first-hand observation of safety processes, in addition to the detailed programmatic compliance checks.

Recommendation (revised): NASA's OSMA should have a coordinated, in-depth system of safety assurance tools and processes to verify effective programmatic safety compliance, system safety practices, safety process function, safety culture, and overall safety posture at all levels of the organization.

Rationale: The Panel believes this would be an opportunity to take a fresh look across the Agency at what is being done to achieve the goal and measure progress. The Panel emphasized that "effective"

means is not just a paper drill (a checklist)—it should be what is actually being done. The Panel wants positive confirmation that the OSMA not only has a policy, but that the policy is embraced across the Agency. The Panel is not asking the OSMA to create something new, but to ensure that what they have is modified or updated to (1) include system safety, (2) verify that the policies and practices are being followed on a daily basis, and (3) identify any "gaps" that are not being covered.

NASA's Response: NASA initially responded on 8/10/18, concurring with the recommendation, which is a revision of ASAP Recommendation 2017-02-01. NASA provided a summary of current and future activities, including deep-dives at selected NASA Centers and documentation of its findings and recommendations for an ongoing performance-based safety and mission success audit process in a State of Capability report. The ASAP reviewed the report and had planned to attend an audit in 2020 to confirm progress. However, with the COVID-19 pandemic, the scheduled audits had to be postponed. The ASAP was able to attend a virtual audit in 2021 and feels the intent of this recommendation has been met.

2017-01-01 Practice of System Engineering and Integration Principles by Commercial Crew Providers for Transportation Services to the ISS

Finding: The investigations into two recent mishaps on commercial launch vehicles have concluded that the mishaps were unrelated because the immediate (or proximate) causes of the mishaps were different. However, in the opinion of the Panel, the underlying root causes of both mishaps can be traced to escapes in the System Engineering and Integration (SE&I) process and controls involving one or more of the following areas: design, analysis, manufacturing, quality control, qualification, and operations (including operational tests).

Recommendation: The Panel recommends that NASA require the Commercial Crew providers to produce verifiable evidence of the practice of rigorous, disciplined, and sustained SE&I principles in support of the NASA certification and operation of commercial crew transportation services to the ISS.

Rationale: Rigorous and disciplined SE&I processes and controls are essential elements of any engineering effort. When dealing with complex systems for human space travel, where inherent risks must be managed to an acceptable level, the emphasis on SE&I and cross-discipline engineering is even more critical. No amount of NASA oversight or insight into the performance of the commercial providers can compensate for a lack of rigor in the providers' SE&I processes and controls. On a regular basis, the commercial providers make numerous important decisions that do not rise to the level of NASA oversight. Their detailed knowledge of the system design, qualification, and performance generally exceeds that of the NASA engineers who provide insight and oversight. Thus, the responsibility

for producing a system that provides an acceptable level of risk for NASA missions to the ISS rests heavily on the commercial providers and their SE&I processes and controls.

Finally, it is important for the provider to not only furnish evidence that rigorous, disciplined, and sustainable SE&I processes and controls are in place, but they should also be shown to be effective over time. This is a foundation for all other certification activities.

NASA Response: NASA initially responded on 5/22/17, concurring with the recommendation. NASA stated that the Commercial Crew providers are responsible for ensuring cost-effective system design, realization, operation, and technical management of the systems they are developing to meet a fixed-price contract. Through contract requirements, deliverables, and insight, the Commercial Crew Program is able to verify and/or validate that SE&I principles are followed to assure the proper management of risks, requirements, interfaces, configuration, and technical data throughout the system life cycle. In addition, the Boeing Orbital Flight Test (OFT) mishap of December 2019 offered additional opportunity for NASA to hone its oversight of SE&I principles.

The ASAP continued to monitor the SE&I practices throughout the development and certification process, and how SE&I "lessons learned" from the Commercial Crew Program promulgate through other human spaceflight programs. The intent of the recommendation has been met.

APPENDIX C

ASAP Members and Staff

Aerospace Safety Advisory Panel Members

Dr. Patricia A. Sanders

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

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

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

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

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

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

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

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

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

For many years, Mr. West actively led or supported standards-developing activities for system safety and other specialty engineering disciplines. From 2010 to 2019, Mr. West chaired the G-48 System Safety Committee, currently under SAE International. He was one of the authors of the G-48 Committee's "Standard Best Practices for System Safety Program Development and Execution," GEIA-STD-0010, and was the sponsor of its first major revision. From 2017 through 2018, Mr. West served as the Vice Chair of SAE International's Systems Management Council. Mr. West served on the BCSP 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 International System Safety Society (ISSS) and was awarded its highest honor, the Professional Development Award, in 2013. He was also named the ISSS Manager of the Year in 2010. Mr. West was active in Toastmasters International from 2009 through 2017 and has been an invited speaker on system safety topics at several national and international events, including the 1st International Helicopter Safety Symposium in 2005, the FAA 9th Annual Commercial Space Transportation Conference in 2006, the Australian System Safety Conference in 2013, and numerous International System Safety Conferences since 2001.

Mr. West earned a B.S. in nuclear engineering from the University of Cincinnati. He holds the Certified Safety Professional (CSP), Associate Safety Professional (ASP), and Certified Hazardous Materials Manager (CHMM) credentials, and he is a registered Professional Engineer (PE). Mr. West enjoys astronomy, bicycling, and traveling.

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

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

Dr. Richard S. Williams is a surgeon and aerospace medicine physician who currently serves as Director of the Three Rivers and the Eastern Shore Health Districts of the Virginia Department of Health. He leads 12 public health departments serving a 2,500-square-mile rural area in Virginia's Middle Peninsula, Northern Neck, and Eastern Shore, responsible for public health care and environmental health support to a population of about 183,000. He is also a Federal Aviation Administration Senior Aviation Medical Examiner, providing aeromedical consultation services for all classes of airmen. Previously, he served as NASA's Chief Health and Medical Officer. He spent 27 years in the U.S. Air Force (USAF) as a general surgeon, flight surgeon, and medical manager and leader, domestically and in contingency operations abroad.

Dr. Williams reported to NASA Headquarters as an Air Force Colonel in 1998. He served as Director of the Office of Health Affairs and entered the Senior Executive Service as NASA's Chief Health and Medical Officer in 2002. He led NASA's health care team through the construction and

initial operation of the International Space Station and the final years of the Space Shuttle Program. His responsibilities included leadership, policy, oversight and advocacy for astronaut health care, NASA employee health care, protection of research subjects, and bioethics. During his 15-year tenure, Dr. Williams led efforts to secure legislative authority for beyond-career astronaut health care, implemented Health and Medical Technical Authority, produced policies on ethics-based risk assessment for astronaut health and medical exposures during space flight missions, and fostered cooperative efforts between NASA's Human Research Program and health care system to better understand space flight–related health risks and mitigations.

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

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

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

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

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

and attached space forces providing tailored, responsive, local, and global space effects in support of national and combatant commander objectives.

General Helms was commissioned from the U.S. Air Force Academy in 1980 and is a distinguished graduate of the USAF Test Pilot School (Flight Test Engineer Course). She has served as an F-15 and F-16 weapons separation engineer and as a flight test engineer for the CF-18. She has also commanded the 45th Space Wing, Patrick Air Force Base, Cape Canaveral, FL, and served as the J5, U.S. Strategic Command.

Selected by NASA in January 1990, General Helms became an astronaut in July 1991. On January 13, 1993, then an Air Force Major and a member of the Space Shuttle Endeavour crew, she became the first U.S. military woman in space. She flew on STS-54 (1993), STS-64 (1994), STS-78 (1996), and STS-101 (2000), and 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.

Mr. William P. Bray

- Vice President, Strategic Business Operations, Frontier Technology Incorporated
- Former Deputy Assistant Secretary of the Navy for Research, Development, Test and Evaluation
- 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 (DRPM) Office

Mr. Bray currently serves as the Vice President for Strategic Business Operations at Frontier Technology Incorporated (FTI). In that role, he leads FTI efforts for Strategy Development and Business Integration.

Mr. Bray retired after 36 years of government service in September 2020, the last 14 years serving in the Senior Executive Service Corps. His last assignment was as the Deputy Assistant Secretary of the Navy for Research, Development, Test and Evaluation (DASN (RDT&E)) under the Assistant Secretary of the Navy for Research, Development and Acquisition (ASN RD&A). In that role, Mr. Bray was responsible for executive oversight of all matters related to Naval RDT&E Budget Activities, Science and Engineering, Advanced Research and Development, Prototyping and Experimentation, and Test and Evaluation. In addition, he was responsible for oversight and stewardship of the Department of Navy Research and Development Establishment which included 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 (MPM) for Surface Navy Combat Systems. Mr. Bray started his career at the Naval Surface Warfare Center, Corona Division, California in December 1984.

Mr. Bray is a graduate from The Pennsylvania State University in 1984 with a Bachelor of Science degree in Petroleum and Natural Gas Engineering, and also earned a Master of Science in Systems Management from the University of Southern California. He was Defense Acquisition Workforce Improvement Act (DAWIA) Level III certified 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. George C. Nield

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

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

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

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

Dr. Sandra H. Magnus

- Principal, AstroPlanetview, LLC
- Former Deputy Director-Engineering in the Office of the Undersecretary for Research and Engineering, Department of Defense (DOD)
- Former Executive Director of the American Institute of Aeronautics and Astronautics (AIAA)
- Former NASA Astronaut

Dr. Sandra H. "Sandy" Magnus is currently the Principal at AstroPlanetview, LLC and a part time Professor of the Practice at the Georgia Institute of Technology. Before joining Georgia Tech she was the Deputy Director of Engineering in the Office of the Secretary of Defense for the Undersecretary of Research and Engineering. In that role she served as the "Chief Engineer" for the DoD establishing engineering policy, propagating best practices and working to connect the engineering community across the department. In addition, she is the former Executive Director of the American Institute of Aeronautics and Astronautics (AIAA), the world's largest technical society dedicated to the global aerospace profession. Prior to leading AIAA, Dr. Magnus was a member of the NASA Astronaut Corps for 16 years.

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

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

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

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

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

Mr. Paul Sean Hill

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

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

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

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

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

Dr. Amy K. 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. Dr. Donahue provides primary leadership and direction for all academic activities and faculty affairs at the Academy.

Dr. Donahue is professor emeritus of public policy at the University of Connecticut (UConn) where her research has focused on executive leadership, homeland security, and disaster preparedness. 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 2011 to 2018, Dr. Donahue served as UConn's Vice Provost for Academic Operations and Chief of Staff to the Provost. Prior to that, Dr. Donahue headed UConn's Department of Public Policy. Previously she advised the Chancellor of Louisiana State University immediately following Hurricane Katrina and was the founding director of LSU's Stephenson Disaster Management Institute.

From 2002 to 2004, Dr. Donahue was Senior Advisor to the Administrator for Homeland Security at NASA and, as the agency's liaison to the Department of Homeland Security and the Homeland Security Council, 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 Columbia mishap. From 2004 to 2007, Dr. Donahue served on the Aerospace Safety Advisory Panel and was recently reappointed to the Panel.

As the Distinguished Military Graduate of Princeton's Reserve Officer Training Corps in 1989, she began her U.S. Army career in the 6th Infantry Division at Fort Wainwright, Alaska. Her military assignments included serving as Officer in Charge of a Forward Surgical Team, as the Training and Operations Officer (S3) for the 706th Main Support Battalion, and as Chief of Mobilization, Education, Training, and Security for Bassett Army Hospital. She moved on to manage a 911 communications center, and to volunteer 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 M.P.A. 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.

Aerospace Safety Advisory Panel Staff Members

Ms. Carol Hamilton, ASAP Executive Director

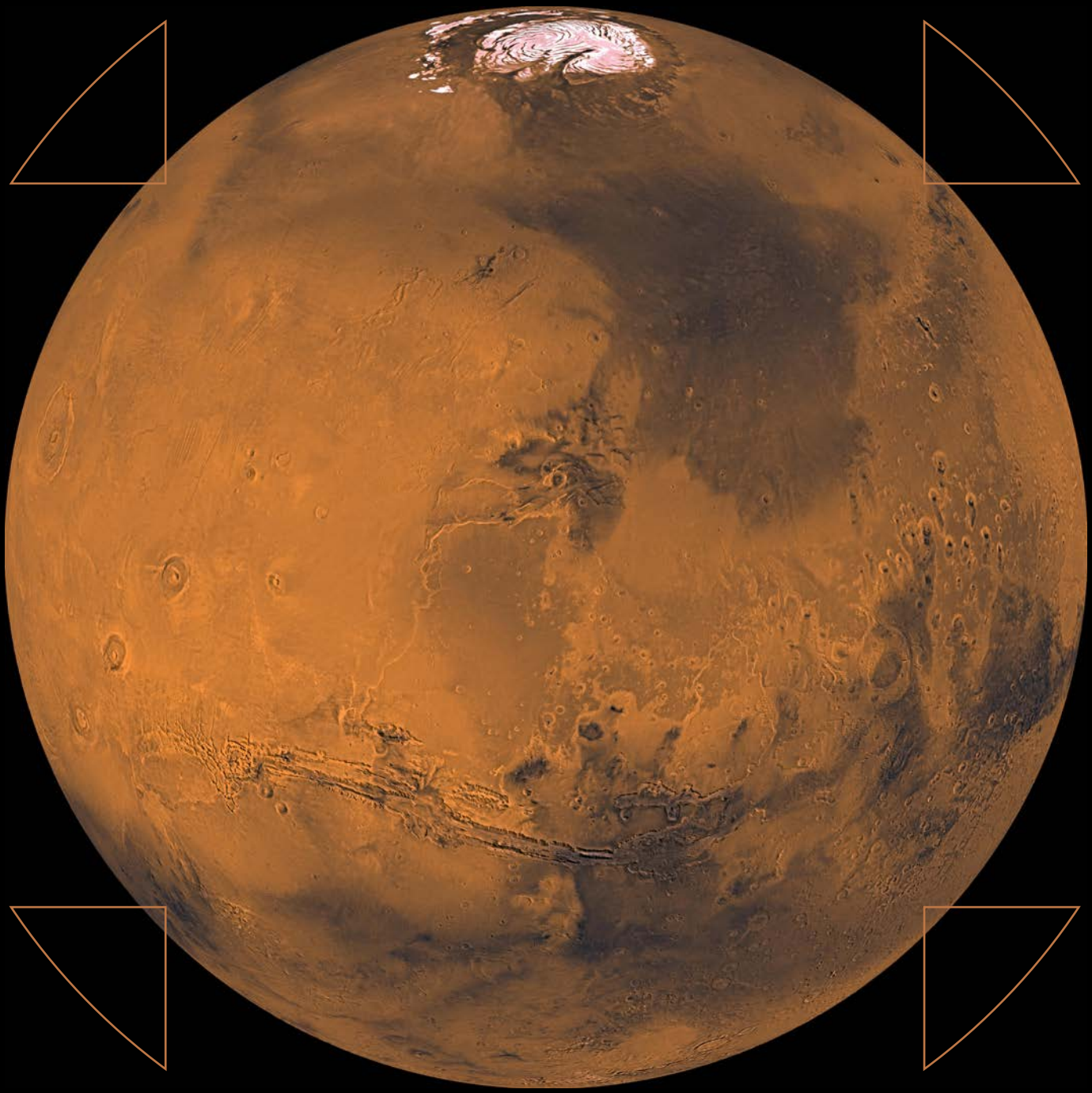
Ms. Carol Hamilton, Executive Director of the ASAP since 2015, has specialized in system safety engineering for more than 25 years. Her career also includes experience in systems engineering, systems verification, and system test engineering for both NASA space systems and the Department of Defense systems.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

Ms. Lisa Hackley, ASAP Administrative Officer

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

Ms. Kerry Leeman, ASAP Annual Report Editor

Ms. Kerry Leeman received B.A. degrees from the University of Houston in philosophy and technical writing. With over two decades of experience as a technical writing professional spanning the aviation, aerospace, petrochemical, and biomedical industries, she joined the ASAP as a technical report writer in 2019. Her prior experience with NASA includes technical writing and editing for the Constellation Space Suit Program and demonstrating the extravehicular mobility unit spacesuit to Houston-area students. She is currently an information security technical writer for the Texas Department of Transportation in Austin, Texas.



...AND ON TO MARS

AEROSPACE SAFETY ADVISORY PANEL

Dr. Patricia A. Sanders, Chair
Mr. William P. Bray
Dr. Amy K. Donahue
Lieutenant General Susan J. Helms, USAF (Ret.)
Mr. Paul S. Hill
Dr. Sandra H. Magnus
Dr. George C. Nield
Mr. David B. West
Dr. Richard S. Williams, MD

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