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

October 5, 2021

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

Dear Sen. Nelson:

The Aerospace Safety Advisory Panel (ASAP) held its 2021 Fourth Quarterly Meeting via teleconference September 21-23, 2021. We greatly appreciate the participation and support received from NASA leadership, the subject matter experts, and the support staff.

The Panel submits the enclosed Minutes resulting from the public meeting for your consideration.

Sincerely,

Patricia Sanders

Patricia Sanders
Chair

Enclosure

AEROSPACE SAFETY ADVISORY PANEL
Public Meeting
September 23, 2021
Conference Call

2021 Fourth Quarterly Meeting Report

Aerospace Safety Advisory Panel (ASAP) Attendees:
Dr. Patricia Sanders, Chair
Lt Gen (Ret) Susan Helms
Mr. Paul Sean Hill
Dr. Sandra Magnus
Dr. Amy Donahue
Mr. William Bray
Dr. George Nield
Mr. David West
Dr. Richard Williams

ASAP Staff and Support Personnel Attendees:
Ms. Carol Hamilton, NASA ASAP Executive Director
Ms. Lisa Hackley, NASA ASAP Administrative Officer
Ms. Kerry Leeman, Technical Writer/Editor

Telecon Attendees:
See Attachment 1

Opening Remarks

Ms. Carol Hamilton, ASAP Executive Director, called the meeting to order at 2:00 p.m. ET and welcomed everyone to the ASAP's Fourth Quarterly Meeting of 2021. She indicated that two emails were received from the public, which were shared with the Panel, and then filed. She also noted that no requests to read statements had been submitted prior to the meeting, but time would be allocated at the end for public comments.

Dr. Patricia Sanders, ASAP Chair, opened the meeting by stating that once again, the ASAP (or the Panel) met virtually and conducted insight and fact-finding engagements through electronic media. As with the rest of the world, the Panel looks forward to the day—hopefully soon—when a return to the benefits of normalcy occurs. Dr. Sanders added that the pandemic continues to impact us all—including NASA with supply chain issues and general workforce fatigue, which the Panel will say more about later—but she appreciates and thanks all those who patiently work through the challenges on a daily basis, and who made the past few days productive for the Panel.

The Panel covered a lot of ground in their discussions this week, but not all areas of interest were included. Dr. Sanders explained that the Panel did not engage with Advanced Exploration Systems (AES)—including discussions on the Human Landing System (HLS)—at the ASAP Fourth

Quarterly meeting due to time constraints and a conflict with other critical programmatic meetings for AES, but they plan to do so in the near future. Additionally, any detailed insight consideration of HLS design is precluded until resolution of the ongoing legal challenges.

Regardless, Dr. Sanders continued, the Panel has been a consistent proponent of adequately resourcing all the complex components necessary for safely executing deep space exploration. Insufficient resources can lead to degraded safety due to premature or unwise design decisions. Insufficient resources for complex and high-risk components can also preclude the ability to carry forward enough competing options until well enough developed to understand the implications for safety and crew risks—whether or not more than one design is eventually employed. The Panel urges a clear-eyed assessment of what resources are needed, what resources are provided, and what can realistically and safely be accomplished. Likewise, the ASAP remains proponents of realistic schedules, consistent with safety and resources.

Dr. Sanders indicated that the Panel continued discussions concerning the strategic issues surrounding the intended role of NASA in a rapidly evolving space community environment. One step was taken by the Agency this week looking toward that future, with the announcement of the reorganization of its Human Exploration efforts. The Panel understands that one of the objectives of this realignment was to decrease the scope of responsibilities of the key leaders in an effort to not only manage their day-to-day portfolios with the immediate pressures of execution, but also to free up some "head space" to look to the more strategic aspects of human space exploration. It will take some time, Dr. Sanders asserted, for change to settle in and for the intended advantages to be realized. The effectiveness of any organizational change depends on its execution. In this case, there are two very capable leaders who will share that responsibility. Dr. Sanders further emphasized that attention to the seams between the two components—development and operations—will be critical to the Agency's success, as will be the communications throughout the entire workforce.

In engaging with programs and contracting personnel, the Panel attempted to delve more deeply into discussing NASA's intended role vis-à-vis its commercial providers. The Panel's consistent interest in this remains ensuring that NASA maintains clear lines of accountability for risk management. Dr. Sander's stated that the Panel recognizes that a balance is necessary: on one hand, NASA, as the customer, needs to demand that its providers be accountable for meeting NASA requirements; on the other hand, the Panel acknowledges that it is in the Agency's best interest, especially in the development of the complex and critical systems required for human spaceflight, to selectively collaborate with the providers in order to take advantage of the talented NASA workforce and decades of accumulated experience, with the ultimate goal for NASA to receive a safe and effective product or service. Dr. Sanders emphasized that it is critical for NASA to understand the dynamics of this continuum, and clearly understand its role and the resultant impact on risk management and accountability. Mixing approaches without defining and executing clear lines of authority and accountability reduces insight into the risk posture and negatively affects safety. Dr. Sanders stressed that it is also equally important for the respective accountabilities to be communicated definitively, explicitly, and with no fuzziness of interpretation throughout the entire workforce of both entities.

Dr. Sanders then asked for comments from the Panel. After pausing for input, she moved on to another topic of interest, stating that with respect to contractual aspects of work with commercial providers, the Panel looked into some of the initial lessons learned from Commercial Resupply Services and Commercial Crew Transportation Capability. She then called on Mr. William Bray to elaborate.

NASA's Strategic Evolution/Contractual Efforts

Mr. Bray noted that the Panel has commented before on—and restated again during the Fourth Quarterly session—the importance for NASA to strategically define its mission, its guiding principles, and its vision for the Agency's leadership role in the future, given the increasing evolution of the role of the private sector and international cooperation. Defining and clearly communicating NASA's role is vital to inform priorities and to organize frameworks and processes in order to execute its missions safely and with a good understanding of the risk involved. Mr. Bray added that as the breadth and types of relationships develop, expand, and become more complex to achieve that mission, having and using the appropriate tools to manage risk are critical. Tools that will become increasingly more important—and that NASA has not traditionally exercised in the safety and risk management process as much—are acquisition processes and contractual structures.

During this Quarterly session, the Panel asked for, and received, briefings associated with contracting efforts, including the Commercial Crew and Cargo Program, the subsequent lessons learned, and how those lessons are being applied to current and future contracts, specifically in the Artemis campaign. As a binding agreement between NASA and industry, the contract forms the basis for execution of the government requirements by the contractor, as well as for establishing the critical relationship between the government and the contractor. Mr. Bray stated that a well-thought-out and executed contract structure can enable collaboration and transparency. More importantly, he added, it will also establish the risk management and acceptance roles as well as authorities between the two parties.

The briefings indicated to the Panel that over the last several years, the individual programs have worked together on a collaborative basis to informally identify a number of best practices and contractual clauses and language, which, based on experience, have emerged in several key areas such as data rights, early contractor feedback on draft requests for proposals, general contract engagement, and adoption of commercial standards. So, Mr. Bray surmised, there is clearly a rich body of knowledge resident across the NASA programs and contracting communities, which is good.

Building from that, the Panel believes, as NASA continues to incorporate a wider variety of acquisition methods, the Agency should consider establishing a more formal and strategic approach to provide a consistent and broadly communicated set of best practices that align with each different acquisition method. Mr. Bray stated that having a top-down process would complement the informal knowledge transfer and ensure that new programs have the essential elements in their contractor relationships that the Agency needs to manage mission risk and crew safety consistently and effectively. In addition, due to the complexity of the Artemis campaign and evolution of requirements over a long period of time, the Panel believes it is also critically important to establish a single, integrated master schedule that incorporates

architectural, systems engineering and integration, testing, and contracting activities to ensure requirements are clearly defined and understood by all, and ultimately appended into the appropriate contract actions.

As a final note, Mr. Bray continued, although it is an important first and necessary step, having a consistent and well-understood approach to what is needed in contracts to manage risk is not enough. The management of the program to fully execute and maintain an objective view of contractor performance and impact on risk definition, acceptance, and mitigation is also critical.

Even in the existing examples of programs that have incorporated lessons learned and appropriately targeted contractual clauses, the Panel observed several instances where the aforementioned risk acceptance line between NASA and the contractor has been blurred. In summary, Mr. Bray stated, NASA needs to assess its interactions with contractors continuously and critically so that collaboration and transparency is present and encouraged, but contractor accountability is also clearly defined, understood, and appropriately applied.

Dr. Sanders then asked for comments from the Panel. Dr. Magnus added that one of the things the Panel has been talking about a lot is the difference between a partner and a customer and what that means in terms of roles and responsibilities, and even to a certain extent, how contracts are derived. So as NASA gets more involved with complex contract structures in the future, it is important for NASA to be self-aware and be mindful of what their role is. There are definitely different roles and accountabilities, Dr. Magnus stated. The Panel wants to emphasize the importance of how the contract methodology is carried out. Mr. Hill then stated that one of the major concerns is that if NASA overemphasizes partnering in all its discussions going forward, there is a risk of not asking the difficult questions in deference to supporting the "partner."

Dr. Sanders thanked Mr. Bray for leading that discussion, and the Panel members for their related comments. She then noted that along with clearly understanding accountability for risk management, the Panel also recognizes that all collaborative endeavors—whether with commercial industry or international partners—occasionally come with some sensitivities relative to public perceptions or geopolitical issues. While respecting these aspects of collaboration and recognizing the value of relationships forged over years, if not decades, the Panel strongly urges NASA to be mindful that internal to the collaboration, these aspects should not be allowed to interfere with sound engineering and safety practices.

The Panel believes that one facet of the NASA strategic evolution should include figuring out how to work with—and perhaps match—the agility of the commercial industry with whom they are working. Dr. Sanders stressed that if the Agency is going to be able to optimally realize the advantages of working with a more agile and innovative commercial industry, NASA needs to reshape itself to be more agile and innovative. She added that given the magnitude of the exploration goals and aspirations facing NASA and the nation, and without sacrificing the underlying engineering rigor, the Agency cannot afford to be stuck in the past using increasingly obsolete practices.

Dr. Magnus added to the conversation that there is not a one-size-fits-all approach anymore, and in having an overarching view of what the Agency is trying to achieve, NASA must be more

flexible and thoughtful up front about the tools in the toolbox. Mr. Bray agreed with Dr. Magnus about how the "tools in the toolbox" concept is very important. He noted that program managers should look at multiple ways to structure contracts over time.

Dr. Sanders mentioned that before providing observations on some of the other discussions the Panel was engaged in, she felt compelled to comment on a long-standing concern and an open recommendation. SpaceX seeks to launch an additional 30,000 Starlink satellites, and while the Panel has no position on the advisability of that action, it does underscore its persistent concern with the lack of a formally designated and resourced lead agency for Space Traffic Management. This continues to be a critical safety concern—a growing safety concern—that remains unaddressed by the Congress, stated Dr. Sanders, and added that this is an overdue and necessary action.

Exploration Systems Development (ESD) efforts were also reviewed by the Panel. Dr. Sanders introduced Mr. Paul Hill who presented the Panel's observations.

Exploration Systems Development

Mr. Hill stated that the Panel reviewed ESD's Artemis I progress, the path and progress from there to Artemis II and beyond, and goals to reduce long-term, sustaining costs. With a stacked launch vehicle in the Vehicle Assembly Building, NASA is well into the familiar and formal final flight preparations for the Artemis I mission. This includes increasingly comprehensive system checkouts and team readiness reviews, Mr. Hill noted. These reviews involve the full range of mission-related facilities and teams, from engineering and flight control teams to the Mission Management Team. Of course, he added, as with most first-time flows, it would not be a surprise to have some hiccups along the way, and NASA's review methodology is intended to catch and fix each problem and smooth the progress through future flows. Mr. Hill observed that ESD is also making progress in Artemis II manufacturing as well as for some long-lead Artemis III and IV items.

Lastly, the Panel was briefed on ESD goals to reduce future costs through process improvements and alternate acquisition approaches, including applying lessons learned from other programs, like the Commercial Crew Program (CCP). The Panel recognizes that NASA's integration efforts become more complex as they progress from Artemis I into the broader Artemis campaign that follows. The Panel will follow up with the Agency as it evolves its management processes accordingly.

Dr. Sanders thanked Mr. Hill for his observations, and moved on to another topic, the architecture aspects of advanced space exploration. Dr. Sandra Magnus was invited to lead the Panel's summary.

Systems Engineering and Integration

Mr. Greg Chavers, Deputy Associate Administrator for Systems Engineering and Integration (SE&I), Human Exploration and Operations Mission Directorate (HEOMD), NASA Headquarters, provided an update. The HEOMD SE&I organization is currently focused on architecting and defining top-level requirements that span across the Artemis campaign. As the Panel has noted frequently through 2021, this work is necessary to define the top-level requirements, to identify

capability gaps for resultant technology investment requirements, and to develop mission concepts of operations for highly complex Artemis mission sets.

However, the Panel views this work as architecture and mission engineering as opposed to the traditional definition of SE&I. Consequently, the Panel has invested a lot of time to understanding the delineation between the work that this group is doing and the type of efforts that are well understood as SE&I—the programmatic engineering work required to design and produce a complex engineering system.

Dr. Magnus stated that the SE&I group is currently tasked with defining the overall architecture, and thus, how each individual element fits the architecture in order to define the top-level requirements that must be met in order for the element to fulfill its necessary function in the overall mission architecture. Prior to transferring those top-level requirements to the acquisition process, the SE&I group also convenes a larger group of stakeholders to understand impacts on other architectural elements. The iterations are performed as needed to derive the optimal set of top-level requirements, which then propagate to all elements, not just to the element that has expressed the immediate need because of an upcoming procurement activity.

Dr. Magnus emphasized that this process, which the SE&I group still needs to document and publish so that it is clear to the whole NASA community and beyond—an important step that should not be delayed—allows the SE&I organization to actively manage and evolve the Artemis architecture. She added that the SE&I group is currently prioritizing its efforts based on the procurement process and the sequence of projects in the acquisition pipeline. Again, the Panel believes the work that SE&I has been doing is a positive first step in helping NASA manage the risk involved in sending humans beyond low-Earth orbit (LEO), but effective execution is hampered by the lack of a single, overall, integrated formal program-driven master schedule and unifying management authority.

As Mr. Bray mentioned earlier when discussing the importance of a strategic and consistent approach to contracting, Dr. Magnus said, the complexity of the Artemis ecosystem, along with the expected evolution of requirements—which involves creating and maintaining an architecture that can be updated, adjusted, and can incorporate the latest in innovation or new technology—can best be managed by an integrated approach. Identifying and understanding enterprise-level requirements—such as communication and other fundamental capabilities—is important to grasp early in the process.

Dr. Magnus reiterated that a master schedule, which outlines the enterprise program across the mission space, defines critical paths, and documents capability development plans, will allow the SE&I team and NASA as a whole to focus on the right set of priorities at the right time in order to optimize top-level requirement flow across the complicated contractual ecosystem, thus minimizing the inevitable changes in designs. In addition, understanding enterprise-level requirements early in the process also helps identify opportunities and areas to pursue open architecture requirement paradigms, which also reduce expensive, complicated, and bureaucratically burdensome design and contractual changes later. A well-thought-out open design approach can also enable sub-component-level design competition in future design iterations. Most importantly, Dr. Magnus stated, this approach also provides NASA with the

ability to manage risk more effectively across the complex integrated system of systems that are required to go back to the Moon and position NASA to go beyond to Mars.

Dr. Sanders thanked Dr. Magnus for her observations. She then indicated that with a very full agenda, the majority of the Panel's time with the CCP was spent on the Boeing component with less emphasis on SpaceX. She invited Dr. George Nield and Mr. Dave West to discuss both providers.

Commercial Human Spaceflight

Dr. Nield started the discussion with observations on recent commercial human spaceflight accomplishments. He noted the following missions:

- Virgin Galactic (VG) SpaceShipTwo: Richard Branson joined several other VG employees on a suborbital flight on July 11, 2021.
- Blue Origin New Shepard: Jeff Bezos, along with the oldest and youngest people to travel to the edge of space, launched on July 20, 2021.
- SpaceX Inspiration4: Four private citizens spent three days in orbit, starting on September 15, 2021.

Dr. Nield indicated that none of the aforementioned flights were NASA missions; they did not use NASA rockets or spacecraft, and none had NASA astronauts onboard. Dr. Nield added that he personally thinks those launches were very significant in terms of marking what could be the beginning of a new era of commercial human spaceflight. In addition to enabling an opportunity for more and more people to personally experience traveling to space, something many have been hoping to accomplish for a very long time, Dr. Nield stated that the following beneficial outcomes may occur from commercial human spaceflight endeavors:

- NASA will have the opportunity to be just one of many customers.
- There is a potential for lower spaceflight costs, increased innovation, new products and services, and new markets.
- The flights may motivate students and teachers about science, technology, engineering, and mathematics (STEM), which will help develop the aerospace workforce of the future.

Dr. Nield then introduced Mr. David West to discuss NASA's human spaceflight program, CCP, starting with SpaceX.

Commercial Crew Program

Mr. West stated that the Panel had the opportunity to engage in some discussions about the current status and recent accomplishments of SpaceX, one of NASA's two CCP providers. At this time, nominal operations of the SpaceX Crew-2 Endeavor vehicle are continuing. All in-flight anomalies associated with the Crew-1 entry and the Crew-2 launch have been formally closed by the CCP, and these closures support the Crew-3 mission and Crew-2 return. The Crew-2 vehicle was relocated from the International Space Station (ISS) Node 2 forward port to the zenith port in July. Crew-3 is on track for an October 31 launch date. Sometime in early-to-mid November, after Crew-3 arrives, Crew-2 will undock and depart. Mr. West noted that this departure will include the first 360-degree fly-around of the ISS by a U.S. vehicle since the Space Shuttle was retired.

The Inspiration4 mission, with four private citizens aboard, successfully concluded on September 18 with a splashdown of the SpaceX Crew Dragon capsule off the Florida coast. While Inspiration4 was not a CCP mission and did not travel to or dock with the ISS, there are nevertheless a few aspects of the mission that are worth noting here, Mr. West indicated. The mission marked the first-ever crewed orbital mission that did not include any professional astronauts. The mission control practices used for Inspiration4 closely mimicked those that SpaceX had previously developed with NASA. The spacecraft for Inspiration4 reached an orbit that was about 100 miles farther out than the ISS's orbit, and higher than a Dragon capsule had previously flown. In addition to having flown higher, Inspiration4 also exercised Dragon's life support system for a longer duration than had previously been done. Mr. West stated that SpaceX has agreed to share data from the Inspiration4 mission with NASA.

While the Panel is impressed with the track record of successes that SpaceX continues to build, it urges the CCP and SpaceX to maintain a high level of vigilance and avoid falling into any sort of complacency that could jeopardize the safety of future missions or astronauts.

Dr. Nield added that the Panel also spent a considerable amount of time talking about Boeing's Orbital Flight Test (OFT)-2 launch attempt on August 3. As a review, during the countdown test of the Service Module (SM) propulsion system manifold isolation system valves, 13 of the 24 oxidizer valves failed to cycle open (8 were associated with the SM reaction control system, and 5 were related to the orbital maneuvering attitude control [OMAC] system). All fuel and helium valves cycled nominally. Dr. Nield indicated that the launch commit criteria require all isolation valves to be functional and open during launch, so after some initial troubleshooting, the launch attempt was called off. Since that time, a fault tree has been developed with participation from Boeing, NASA, and the valve manufacturer to address all possible causes. Troubleshooting on the pad, in the Vertical Integration Facility, and in the Commercial Crew and Cargo Processing Facility has resulted in additional valve movement, Dr. Nield noted. The partial disassembly of the OMAC pilot isolation valves on the vehicle has been completed to inspect areas of possible stiction. An evaluation is also being conducted of known hypergol compatibility issues for SM prop valve components. Additional off-vehicle valve testing is being considered to attempt to repeat the failure mode. In terms of the path to OFT-2, hardware impacts remain to be determined and could range from minor refurbishment of current SM oxidizer isolation valve components to the need to assign another SM to the OFT-1 mission.

After the OFT-2 launch attempt, the Atlas V booster for the OFT-2 and LUCY missions were swapped, Dr. Nield stated. Once the investigation has been completed and technical issues resolved, he noted, NASA, Boeing, United Launch Alliance (ULA), and the Department of Defense will need to determine a new launch window based on the range schedule, ISS status, and ULA manifest availability. Depending on how large the impact is to follow-on Starliner flights, it will also be important to keep track of ULA's planned transition from the Atlas V to Vulcan, and how that may affect future Starliner missions, Dr. Nield added.

Separately, a lot of work has been done by Boeing and NASA to study the margins on asymmetric parachute loading; however, the NASA technical team has concluded that no major redesign of the Boeing main parachute is required, Dr. Nield continued. As the Panel reflects on how things have unfolded, there have been some positive signs, along with some potential

warning signs, which will be watched closely going forward. On the positive side, Dr. Nield noted, there has been good progress with the hardware, software, and development of procedures. The issues encountered on OFT-1 appear to have been resolved. Also, the Boeing and NASA teams responded appropriately, Dr. Nield observed, and did not launch once problems were found during the lead up to OFT-2.

He noted some potential warning signs, however. Some rather significant differences were evident in how several safety issues were assessed between NASA and Boeing during the Flight Readiness Review presentations. Both teams were in agreement on what the key issues were, but ideally, there would be a consensus on the magnitude of the risks that were being accepted, Dr. Nield stated. It also concerns the Panel that Boeing and NASA got so close to launch without having identified the valve problem. Dr. Nield noted that the Panel will be interested to see whether any changes can be made to hardware inspection, testing, vehicle processing, or checkout that would minimize the chances of that happening in the future.

Dr. Sanders thanked Dr. Nield and Mr. West for their observations concerning the CCP. She then stated that since the Panel's last Quarterly, an Organizational Safety Culture assessment was conducted collaboratively between NASA and Boeing, as had been performed earlier between NASA and SpaceX. As is the norm for such assessments, Dr. Sanders indicated, the results belong to Boeing, who are the ones who must take real ownership of the findings and take action as appropriate. The feedback the Panel does have—naturally limited—indicates both strengths and challenges. The Panel considers this type of assessment to be a valuable and important undertaking, not to be treated lightly. Dr. Sanders mentioned that she has heard it said many times, that the sign of a healthy safety culture is the continual critical questioning of what could be done better. As a result, the Panel encourages Boeing—and all of NASA and its providers—to continue to question where improvements can be made and to take action to do so.

Dr. Sanders moved the discussion on to the ISS, an area always rife with a lot of activity. She asked Mr. Hill to inform the meeting attendees of the Panel's observations.

International Space Station

Mr. Hill stated that the ISS program reviewed the current flight and crew rotation plans and the Increment 66 status. The Panel also heard the latest ISS life extension efforts, with the U.S., Japan, Canada, and Europe having completed analyses to certify the space station through 2028. Roscosmos has formally extended the Russian segment through 2024, with future work to extend to 2028. The ISS program is studying the steps required to extend beyond 2028, the results of which will influence further work to reach 2032 or later.

The Panel applauds the program's proactive approach in addressing the spacecraft's lifetime extension and in ensuring that all international partners participate in the formal analyses at each step.

Mr. Hill noted that the ISS program continues efforts to extend the working lifetime of the existing extravehicular mobility units (EMUs) to at least 2028. The Panel still has an open recommendation from 2019 to expedite the transition to the next-generation suit before the risk to U.S. extravehicular activity capability posed by the aging EMUs becomes unmanageable.

The Panel also reviewed two serious ISS issues that are still open work: an ongoing cabin pressure leak; and the anomalies during the July 21 Multipurpose Laboratory Module (MLM) flight. On the first issue, a Russian Commission was established to address leak-related cracks in the hull of the Service Module Transfer Tunnel, which first manifested as an increased ISS leak rate in 2019. As reported in previous ASAP meetings, cosmonauts repaired two pressure shell locations in early March 2021, which reduced the leak rate but did not fully mitigate it. Russians continue to investigate a range of possible root causes, and the U.S. is collaborating with a number of engineering analyses at Johnson Space Center (JSC), Langley Research Center (LaRC), the NASA Engineering and Safety Center, and Boeing. The Panel looks forward to further progress in the program's understanding and mitigation of this critical issue.

Mr. Hill acknowledged that the MLM experienced in-flight anomalies on the day of launch. The Russian team worked around these anomalies and the MLM docked eight days later, experiencing one or more anomalies during the post-contact steps during docking. ISS structures and mechanisms have been cleared for operations. A NASA team is actively working with their Russian counterparts who are investigating the anomalies. Again, the Panel looks forward to the final report as soon as it is available, and the lessons learned that are applicable to future ISS operations.

Dr. Sanders added that Station management and crew handle the day-to-day issues competently and make it seem easy—business as usual—but there are serious and critical safety issues faced frequently, and it is beneficial to be reminded of the complexity and consequences of these issues. Regarding the MLM, Dr. Sanders acknowledged the excellent real-time coordination between Russian and U.S. Mission Control teams to work the immediate resolution involving all aspects of Station safety.

Dr. Sanders then asked Dr. Nield to address updates on Commercial LEO Development (CLD) activities.

Commercial Low-Earth Orbit

The Panel spoke with Ms. Angela Hart, Manager, CLD Program, NASA-JSC about several program components, including commercial LEO destinations, private astronaut missions (PAMs), the Axiom Commercial Segment, demand stimulation, and commercial use activities. Dr. Nield stated that proposals for CLD Phase 1 Funded Space Act Agreements were received on August 26 with strong industry response: almost one dozen proposals were received from a diverse set of companies, which is a strong signal that NASA's CLD strategy is sound.

Additionally, the Crew Requirements Working Group held its kickoff meeting on August 25 and distributed candidate crew safety and habitability requirements for review by technical authorities from Safety and Mission Assurance, Engineering, the Flight Operations Directorate, and the Office of the Chief Health and Medical Officer (OCHMO). Representatives were also present from the Crew Office, the ISS, and the CCP. Dr. Nield noted that another team of experts, a Service Requirements Working Group, meets monthly and reviews top-level requirements.

The plan to certify commercial LEO platforms and ensure crew safety, which the Panel thinks will be extremely important, is still in development and will be finalized as part of the CLD Phase 2 Certification and Services contract.

Dr. Nield captured the following key takeaways from the Panel's interaction with Ms. Hart:

- As NASA continues to look at continuing to operate ISS until 2028 or 2030, there is a need to ensure a certified commercial replacement is up and operating once ISS reaches the end of its life.
- NASA should clearly communicate its expectations to industry regarding requirements and timelines to ensure an overlap is present with ISS.
- Sufficient funds need to be in place and available soon enough to allow that overlap to happen. Absent appropriate and timely funding, there is a risk of a gap, since the only thing that can give way is the schedule.
- To ensure that the Agency captures the necessary lessons learned in this new commercial dynamic, the Panel recommends that there be a deliberative post-mission analysis after every PAM, with the participation of the crew and mission control teams, to capture successes, challenges, and other critical implications on assumptions, certification plans, safety and risk training, and other aspects of PAM integration with the ISS program.

Dr. Sanders thanked Dr. Nield for his perspectives on commercial LEO efforts.

She segued to another topic of interest to the Panel. In the competition for the "hardest job in NASA," she stated, Dr. JD Polk, the Chief Health and Medical Officer is definitely a candidate. The Panel, she added, spent some quality time with Dr. Polk, who discussed some ongoing issues the OCHMO is currently facing as well as an update on radiation exposure standards. Dr. Sanders invited Dr. Amy Donahue to elaborate.

Human Health and Performance

The Panel had an opportunity for a conversation with Dr. Polk about several topics being tracked, namely COVID-19, some technical authority considerations, and the updated radiation exposure standards. Of course, Dr. Donahue stated, the pandemic continues to affect all of our lives and workplaces, and this is certainly true at NASA. A high proportion of the NASA workforce is vaccinated, which is allowing a safe return to work in person. NASA, like all federal agencies, is working to understand and implement the President's mandates regarding vaccination and testing, including what reasonable accommodations for exemptions will be made. This is relatively well specified for medical exemptions.

According to Dr. Polk, the biggest challenge with regard to testing and vaccination is implementation of requirements with the large contractor workforce. There are a lot of details to work through, made more complicated by the evolving environment—both in terms of potential emerging variants and recommendations regarding booster shots. And, of course, the ongoing stress of COVID itself and the difficulty of dealing with the pandemic is wearing on everyone, including the NASA workforce.

Dr. Donahue indicated that with respect to technical authority work, the OCHMO is engaged with Boeing on a variety of issues, including parachutes, in particular seeking to understand two-chute pendulums; Starliner suits, where they're looking to enhance crew survivability; and some human factors topics that need attention in terms of functional testing. These are things the Panel will continue to track, but it is comfortable with NASA's engagement.

Finally, Dr. Donahue noted, as discussed at the ASAP Third Quarterly Meeting, after two decades of long duration spaceflight experience on the ISS, and the ongoing results of the Lifetime Surveillance of Astronaut Health, NASA convened a couple of panels (first a virtual expert panel and then a panel of the National Academies) to reconsider the space radiation career exposure standard. The new standard is still tied to the risk of cancer and radiation exposure-induced death (REID), but now has been adjusted to account for industry benchmarks, occupational comparators, and also actual cancer incidence.

The upshot of this review, Dr. Donahue stated, is that the existing exposure limits were deemed to be more stringent than necessary, and the standard more restrictive than is typical of other health standards, which has potential negative implications for career opportunities. Hence, the standard has been revised. The maximum lifetime exposure is now set at 600 mSv, which is an increase, though it maintains a 3% mean REID and is 40% lower than the limit NASA's international partners use. Dr. Donahue indicated that this limit is the same regardless of sex, which is also a change. This is expected to enhance opportunities for both women and men in lunar missions, and it makes Mars missions more feasible. Dr. Polk discussed the trade space around shielding and exposure types and sources, and ultimately the Panel came to understand that while the best practice is to minimize exposure, the Panel feels comfortable that NASA's approach of setting a career limit is appropriately protective against mortality from cancer caused by radiation exposure.

Dr. Sanders thanked Dr. Donahue for presenting the Panel's discussion points on human health and performance issues.

Dr. Sanders stated that in early 2020, Administrator Bridenstine requested that the ASAP take a look at the safety aspects of the long-term sustainability and operations of NASA's aviation assets. That was completed before his departure, but the recommendations the ASAP made were taken onboard by the new leadership, and the Panel was recently provided with their disposition of those recommendations. Dr. Sanders asked Mr. West to summarize the take-aways.

NASA Aviation Safety

The bulk of the work for this study was done by a task force consisting of a subset of ASAP members. In May and June of 2020, a series of virtual meetings was held with key personnel from NASA's Aircraft Management Division, the Aeronautics Research Mission Directorate, the Office of Safety and Mission Assurance, and selected NASA Centers. The Panel's findings and recommendations were based on data compiled from interviews conducted during these meetings. These findings and recommendations were summarized in the ASAP 2020 Annual Report.

Last week, the Panel had the opportunity to discuss the organizational and strategic changes that NASA has made in response to the Panel's aviation safety recommendations.

The Panel advised NASA to move the Aviation Management Division (AMD) to the Office of Safety and Mission Assurance (OSMA) to provide a direct line to the Associate Administrator or to the Administrator, when required. Aircraft management roles have been realigned to support mission requirements. Aviation Safety functions within AMD have been realigned to the OSMA, while responsibility for Capability Portfolio Management has been assigned to the Mission Support Directorate, Mr. West indicated. Implementation remains the responsibility of the Center Directors. Related policy documents have been realigned to the new organizational structure, and the Agency has provided additional funding to the OSMA for the Aviation Safety Program. An Aircraft Management Advisory Board has been established, with membership from the Mission Directorates and Regional Leads. This Advisory Board allows for focused discussion on investment and divestment strategies, along with access to commercial air services.

The Panel advised that the AMD, NASA Safety Center, and Aviation Office should collaborate on a yearly basis to review aviation safety metrics, ensuring that they include proactive and predictive ones. NASA has indicated that the OSMA, in assuming responsibility for the Aviation Safety Program, will partner with the Portfolio Lead and the Centers to reassess metrics.

In response to the Panel's concerns about workloads required for commercial air services (CAS), NASA has implemented a process using qualified contractors to conduct CAS reviews. This process has significantly reduced the workload on the Centers, Mr. West informed. The NASA Safety Center and the Aviation Safety Program are reassessing training requirements for all personnel working on the aviation program. Finally, best practices and lessons learned will be compiled and shared throughout the NASA aviation community.

The Panel was pleased to see the realignment of responsibilities and related changes that have been made in response to its findings and recommendations. The Panel expects that NASA will realize long-term benefits from these strategic actions.

Dr. Sanders thanked Mr. West for his comments on the status of aviation safety activities at NASA.

She stated that during the past quarter, several members of the Panel observed one of the periodic safety audits that NASA routinely conducts. Dr. Sanders asked Dr. Donahue to share her observations on this topic.

Operational Safety Audit

Dr. Donahue was one of the ASAP members who had the opportunity to observe the two-week Institutional, Facility, and Operational Safety Audit the OSMA held for the Stennis Space Center in August 2021. Everything seemed to go very smoothly, she noted. The Panel members present were impressed that the OSMA was able to complete a meaningful audit process almost entirely virtually. Dr. Donahue stated that the OSMA accomplished this by holding many virtual meetings and relying on hundreds of photographs taken to support the audit so that the auditors could still get "eyes on" the physical environment, although the audits were not in person.

Just to get to the punch line first, Dr. Donahue said, the OSMA identified no "catastrophic" or "major non-compliances." The eleven "non-compliances" identified—which are not many—were judged to be relatively common and not unexpected. The result was certainly very encouraging, but what most struck the Panel attendees was the positive demeanor the auditors conveyed and the healthy, helpful dialogue throughout. The Panel members also like the transgenerational learning structure OSMA has created in their audit program. This has a couple of dimensions, Dr. Donahue indicated. First, the audit process is set up so that the center undergoing an audit has an opportunity to learn from the experiences of the Center that most recently went through the process, and likewise they also "pay it forward" by informing the next Center in line. This keeps the process productive rather than positioning it as a "gotcha exercise." Second, Dr. Donahue continued, Centers also contribute auditors to the endeavor. This not only demystifies the process but also helps build a community of practice around safety. Overall, the ASAP was impressed by the process. Dr. Donahue conveyed that the audit seemed very open, professional, collaborative, and cordial overall.

Dr. Sanders thanked Dr. Donahue for her insights on the OSMA's operational safety audit. Before she concluded the ASAP Fourth Quarterly Meeting, Dr. Sanders opened up the meeting for public comments. No comments were received.

Dr. Sanders thanked all the participants and adjourned the meeting at 3:12 p.m. ET.

ATTACHMENT 1

Note: The names and affiliations are as given by the attendees, and/or as recorded by the telecon operator.

PARTICIPANTS

A.C. Charania	Blue Origin
Alan DeLuna	American Astronautical Society
Apollo Muloneo	Industry Enthusiast
Bretton Alexander	Blue Origin
Damien Mills	Boeing
Danny Leantz	NASA Space Flight
Dave Huntsman	NASA Retired Consultant
David Milman	No affiliation information provided
Debra Fresili	Boeing
Deirdre Healey	NASA HQ OSMA
Diane Rausch	NASA HQ
Dillon MacInnis	SpaceX
Dimitra Tsamis	NASA OID
Eric Berger	Ars Technical
Erin Cohen	US GAO
Erin Kennedy	CAO
Jamie DeCoster	Member of the Public
Jamil Castillo	Coalition for Deep Space Exploration
Jared Stout	Director of Congressional and Regulatory Policy
Jeff Foust	Space News
Joel Graham	Senate Commerce
Joey Roulette	The Verge
Jonah Halperin	Horace Greeley
Josh Barrett	Boeing
Josh Finch	NASA
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Laurie Glasson	Boeing
Lewis Groswald	Lockheed Martin
Linda Karanian	Karanian Aero Space
Marcia Dunn	AP
Marcia Smith	Space Policy Online.com
Maribeth Davis	Boeing
Mark Carreau	Aviation Week
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Michael Sheetz	CNBC
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Michelle Murray	FAA
Miguel Gonzalez	The Boeing Company
Micah Madenbuerg	Wall Street Journal
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Monica Witt	NASA Office of Communications
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