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

November 9, 2022

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

Dear Sen. Nelson:

The Aerospace Safety Advisory Panel (ASAP) held a two-part 2022 Fourth Quarterly Meeting in-person at NASA Marshall Space Flight Center, September 27-29, and at NASA Headquarters, October 25-27, 2022, culminating in a public meeting. We greatly appreciate the participation and support that were 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
Chair

Enclosure

AEROSPACE SAFETY ADVISORY PANEL
Public Meeting
October 27, 2022

2022 Fourth Quarterly Meeting Report

Aerospace Safety Advisory Panel (ASAP) Attendees:
Dr. Patricia Sanders, Chair
Mr. Paul Sean Hill
Mr. William Bray
Dr. Sandra Magnus
Mr. David West
Dr. Richard Williams
Dr. Mark Sirangelo

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

Telecon Attendees:
See Attachment 1

Opening Remarks

Ms. Carol Hamilton, ASAP Executive Director, called the meeting to order at 1:30 p.m. EDT and welcomed everyone to the ASAP's Fourth Quarterly Meeting of 2022, held at NASA Headquarters. She indicated that this meeting is an extension of the quarterly, which originated at NASA Marshall Space Flight Center in September 2022. Ms. Hamilton noted that the Federal Registry Notice gave the public the opportunity to send safety-related statements or to make opening comments prior to the scheduled meeting. It was noted that no such comments or statements had been submitted prior to the meeting, but time would be allocated at the end for public comments.

Dr. Patricia Sanders, ASAP Chair, stated that fact-finding for the ASAP's Fourth Quarterly Meeting of the year occurred incrementally over the past two months within the backdrop of a number of critical launch events for the Agency, including discussions hosted by the Marshall Space Flight Center in September and continuing engagement at NASA Headquarters. The Panel appreciates the support of both hosting facilities and the participation of numerous NASA personnel. In addition, Dr. Sanders stated, a contingent of the Panel—at the request of NASA leadership—initiated insight into the safety aspects of the X-plane testing at Armstrong, as this activity resumes after many years of relative X-plane inactivity.

The Panel's discussions were conducted as NASA continues the gradual return to normal operations and recovery from the pandemic and conducts missions within the context of geopolitical tensions. The Panel persisted in its focus on strategic risk management issues along with engaging in looks at the safety of ongoing programmatic efforts. Dr. Sanders noted that with respect to the latter, as usual, the Panel discussed the status of the performance of both providers for the Commercial Crew Program (CCP). She added that Mr. Steve Stitch, CCP Program Manager, and his support staff, continue to have a full plate successfully launching Crew-5 to the International Space Station (ISS) and safely returning Crew-4, while addressing the multiple issues remaining to get to a Crewed Flight Test with Boeing. Dr. Sanders than asked Dr. Mark Sirangelo to summarize the Panel's observations on that topic.

Commercial Crew Program

A number of important milestones have been accomplished in 2022 by the CCP and since the Panel's last public meeting. Dr. Sirangelo remarked that these milestones include conducting an active fleet following of pertinent launch vehicles (Atlas V, Falcon 9) and spacecraft Crew Dragon missions, including Inspiration-4, Axiom-1, and other future missions. There has also been the execution of the SpaceX direct handover on the Crew-4 mission and the successful launch and docking of the Crew-5 mission.

The Panel also noted that NASA has purchased additional missions with SpaceX to meet crew rotation through much of the ISS's expected remaining lifetime, including the potential of a life extension to 2028 or 2030, which will be further discussed in this meeting. There was an additional award of five crew missions, Post Certification Missions (PCMs)-10 to -14, made to SpaceX on August 31. These missions are in addition to PCMs-7 to -9, awarded to SpaceX earlier in the year. At current flight rates, these additional awards will provide crew access to the ISS into 2027.

Dr. Sirangelo noted that these awards have been made, in part, due to the continued uncertainty of the CCP in-service date of the Boeing Crew Space Transportation (CST)-100 crew vehicle. That vehicle has its next test flight schedule during the first half of 2023, with a first operational mission to occur months after that. NASA reported that Orbital Flight Test (OFT)-2 met over 250 flight test objectives and 15 mission operations demonstrations during its test flight. However, it also produced several in-flight anomalies, which will need to be worked prior to the next test. Also, Dr. Sirangelo stated, there will be additional Avionics and Software Integration Lab (ASIL) testing of the new flight CST software drop prior to mission execution, and it will likely generate high-priority software issues. The CCP is also tracking several concerns for the CST program including the path to PCM-1/PCM-2, land load issues, launch vehicle transition over the long-term, as well as hardware sparing, which will further delay the second source provider coming online.

While it is fortunate that the U.S. has one operating ISS crew launch provider, Dr. Sirangelo echoed the Panel's continued concern with the impact of the ongoing delays of the CST-100 program on the CCP. This concern includes leaving the U.S. without a second ISS crew launch provider and the absence of a redundant crew launch system.

Dr. Sirangelo added that the CCP has been evaluating—and has made progress—with SpaceX in identifying and partnering on the mitigations necessary to minimize the impacts to CCP missions due to the expected future SpaceX Starship/Super Heavy ground and launch operations. It is currently SpaceX's intent to launch both CCP launches as well as commercial Starship launches from Pad 39. The Panel

believes it remains critical to ensure that any issues related to a launch failure of Starship and its related vehicles not impact the ongoing operations to provide crew and cargo to the ISS.

The mitigations being explored include ensuring the protection and recovery of Launch Complex-39A critical assets from any non-NASA launch issues; the program participating with SpaceX on the readiness of Starship and its checkpoints/operational reviews; monitoring the configuration and stability of operations at the SpaceX Boca Chica launch site; and the ongoing modification of Space Launch Complex SLC-40 as a backup for crew and Commercial Resupply Services missions.

The Panel has especially noted and expressed their strong support of this last point: the advancement of Pad 40 as a viable backup launch pad. Dr. Sirangelo noted that progress has been made in the readiness efforts at Pad 40, which needs to rapidly continue. These initial efforts include doing a full pad delta upgrade assessment, understanding the certification process and scope, and creating phases for partial and full certification. The Panel understands that SpaceX is targeting completion of the Starship supplement pad on 39 by the end of 2022. It is the Panel's view that these efforts for Pad 40 need to be solidified prior to the beginning of the Starship launch cadence.

The Panel has also been made aware of, and has discussions with, the program concerning the debris issues, which have occurred from the Dragon Crew-1 trunk disposal. Four pieces of debris, after its reentry in May 2021, have been identified as impacting Australia. The number and size of the debris pieces may challenge the process requirement of limiting orbital debris included in the CCP contracts with SpaceX and industry. Dr. Sirangelo stated that to date no debris has been reported from a Crew-2 trunk reentry in September of this year.

NASA and SpaceX are working together to complete a complete analysis of this debris concern. CCP and SpaceX expect to apply this learning future launches. In addition, the results of this work will be shared across NASA and with industry to increase understanding and awareness and to provide a lessons-learned report. Dr. Sirangelo closed his comments by noting that this is especially important as the volume of such launches increase and as NASA explores the deorbit plan for the ISS.

Dr. Sanders added that of course, the value of the CCP is in providing assured access to the ISS. She invited Dr. Sandra Magnus to discuss the Panel's interactions with that mission.

International Space Station

Dr. Magnus observed that the ISS program continues to execute its mission successfully, balancing a very busy schedule of diverse visiting vehicles and a robust research agenda. The Panel has a very small list of watch items, however, that the program was able to provide updates on during the ASAP 2022 Fourth Quarterly Meeting.

At the conclusion of EVA 80 in March 2022, the crew reported water in one of the helmets. Since that time, NASA has had the Extravehicular Activity Unit (EMU) returned for examination to explore the root cause of the phenomena. Dr. Magnus indicated that the space suit has been disassembled and subjected to extensive testing; the likely root cause for the water in the helmet was identified as a "sublimator carryover," a situation that occurs when the suits' ability to remove water is overwhelmed. Crew thermal load is the driver that determines the amount of water that must be eliminated through the cooling system. NASA has developed an operational mitigation plan to periodically remind the crew to monitor and adjust the space suit thermal settings to better manage the thermal load. Additional

absorptive pads have also been added to the helmet. Thus, while the Panel continues to be concerned about the long-term sustainability of the ISS EMUs given their age, the resolution of the most recent water intrusion issue is reasonable. In tandem, NASA is in the middle of an acquisition process for the replacement ISS space suit, and the Panel looks forward to hearing more about the timing and deployment of the new suit and how the above issue will be managed in future suits.

Dr. Magnus stated that the ISS program continues to investigate the source and root cause of the PrK leaks. The PrK is the aft compartment of the Service Module and has a commonly used port for Russian visiting vehicles. Known leak sources have been contained, and the overall stack leak rate has been monitored closely, she added. The hatch between the PrK and the rest of the Station volume is being closed when access to the PrK is not required. So, currently, the on-orbit status is stable, Dr. Magnus noted. Investigations on the ground continue and the ISS program has mapped out an extensive testing program to understand and identify the root cause. The Panel recognizes that the program is doing everything it can to manage the situation in a safe and responsible manner but remains concerned that the reason for the cracks is still unknown. The Panel will be following up with the ISS program on this topic as the results from the ground investigations emerge.

The Panel had a previous recommendation, 2012-01-02, "ISS Deorbit Capability," which stated:

> **Recommendation**: (1) To assess the urgency of this issue, NASA should develop an estimate of the risk to ground personnel in the event of uncontrolled ISS reentry. (2) NASA should then develop a timeline for development of a controlled reentry capability that can safely deorbit the ISS in the event of foreseeable anomalies.
>
> **Rationale**: An unexpected, emergency event could precipitate the need to deorbit the ISS at any time. Timely development of the plan on how to respond to such a situation before it occurs will allow an optimum response and maximize the safety to the public in such a situation.

The Panel closed the recommendation in 2020 based on the fact there was conceptual agreement on an approach and a final agreement was imminent. Subsequent detailed discussions amongst the ISS partners have identified technical and operational issues, which need further addressing, so the Panel is returning to this topic. The urgency, first highlighted in 2012, remains, Dr. Magnus stated. Discussions are ongoing between NASA and the Russian Space Agency to make the controlled deorbit plan more robust. The Panel would like to reiterate its concern, first stated in 2012, about the lack of a well-defined, fully funded, controlled re-entry and deorbit plan for the ISS that is available on a timeline that supports the planned ISS retirement. Furthermore, Dr. Magnus emphasized, the ISS partners are operating at risk today without the capability to deal with a contingency situation that would lead to a deorbit. The risk to public safety and space sustainability is increasing every year as the orbital altitudes in and around the ISS continue to become more densely populated by satellites, increasing the likelihood that an unplanned emergency ISS deorbit would also impact other resident space objects.

The Panel hereby issues the following new recommendation:

> NASA should define an executable and appropriately budgeted deorbit plan that includes implementation on a timeline to deliver a controlled re-entry capability to the ISS as soon as practicable—to be in place for the need of a controlled deorbit in event of

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

Continuing the Panel's assessment of the risk management posture of NASA's efforts, Dr. Sanders called upon Mr. Paul Hill to provide an update on observations of the Artemis and Moon-to-Mars endeavors.

Artemis and Moon-to-Mars

Mr. Hill noted that it's an exciting time in the Artemis campaign with so much flight hardware in various levels of preparation for launches that will take astronauts around the Moon on Artemis-2 and to the surface on Artemis-3. In addition to the Space Launch System (SLS) and Orion, which are well into production, Gateway flight elements, the Human Lander System (HLS), and the next generation EMU are well into formal development, all with a focus on taking Artemis from a plan to missions.

Artemis-1

Progress continues toward a November 4 rollout and November 14 launch, and no significant issues are currently in work, Mr. Hill stated. Although NASA has had some challenges in launching Artemis-1, the Agency has learned a number of cryogen loading lessons through its series of launch preparations and problem resolutions.

Mr. Hill indicated that the team had some rough spots in managing liquid hydrogen (LH2) loading during the last launch attempt, for example:

- An incorrect command initiating LH2 flow to the SLS core stage at a higher initial pressure and chill rate than intended.
- Hydrogen leaked from the 8-inch fill and drain quick disconnect.

As a result, Mr. Hill said, Kennedy Space Center (KSC) replaced the quick disconnect seal, reinforced the use of preloaded commands to reduce the risk of command errors, and re-emphasized the reporting process of anomalies during the launch count. The Panel observed that this kind of challenge will be an ongoing watch item in the relatively lower frequency SLS launch rate versus KSC's Shuttle experience.

Artemis-2

The Orion crew module is the current critical path for Artemis-2 and Artemis-3. That said, Mr. Hill emphasized, progress is being made despite supply chain and processing challenges at KSC.

Gateway

Mr. Hill indicated that the Maxar-provided Power and Propulsion Element (PPE) is based on an existing spacecraft design that has flown more than 100 missions, but development challenges have been discovered for the Maxar PPE design and capability mismatches to Artemis mission requirements. Although the Gateway program is coordinating detailed engineering changes to resolve the technical impacts, the Panel suggests that this kind of disconnect is inherent in a process through which premature design decisions are made at a conceptual level in the absence of a focused, programmatic strategy and clear understanding of interface requirements that then drive development and

procurement. This is an example of the driver for the Panel's focus on the Artemis campaign's program structure and rigorous technical integration approach.

Human Landing System

SpaceX experienced a well-publicized "high energy event" July 11, 2022, while testing Starship Booster 7. SpaceX is still pursuing an aggressive Starship development and test plan, but this failure resulted in corrective actions to increase systems engineering and risk management rigor. All good things and not unexpected in this difficult work, Mr. Hill affirmed.

While NASA has HLS "insight" activities based on Commercial Crew experience, the Panel was reminded that this is a SpaceX development. Detailed design and related design trades are SpaceX's to make, and their work is then reviewed for acceptability by NASA. Mr. Hill informed that the process has evolved from Commercial Crew, and it appears to be working well.

Exploration Extravehicular Mobility Units

Mr. Hill stated that although the Panel will not discuss specifics about the contract awards, Ms. Lara Kearney, Manager, Extravehicular Activity and Human Surface Mobility Program (EHP), accomplished the near-impossible in explaining the Exploration EVA System's procurement strategy and demonstrating the benefit to the Agency in this "hardware as a service" approach. In an Indefinite Delivery–Indefinite Quantity like approach, NASA will award incremental task orders for next capabilities from ISS suits through lunar surface suits. The contract includes "on-ramps" for other vendors to make competing bids, and the government has contractual rights to use all data and designs for government purposes through which these on-ramps could be exercised with the existing systems.

Mr. Hill noted that like HLS, the EHP program has applied lessons learned from Commercial Crew and HLS in establishing insight and management processes. The Panel sees great opportunity to reduce next-generation EMU development and logistics costs, while maintaining NASA's access to the designs.

Mr. Hill reiterated that it is an exciting time as NASA shifts further into actual production for missions that will take astronauts back to the Moon and set the stage for the next decade and more in NASA's exploration mission.

Dr. Sanders noted the importance of an effective program management to include attention to requirements determination and integration for mission success. To continue with the discussion of the Moon-to-Mars challenges, Mr. William Bray was invited to discuss the critical safety areas of architecture and systems engineering and integration (SE&I).

Technical Integration

Mr. Bray stated that the Panel is very satisfied with the continued progress regarding the Artemis mission architecture development and definition, the Artemis SE&I, and the tight coupling of these efforts to support a long-term integrated engineering plan for the Artemis program and campaign. The maturation and advancement of the architecture and SE&I processes, delivered artifacts, and the programmatic integration from the mission level to program elements continues to be impressive and the Panel views this as critically important for the management and resolution of technical and safety risks.

On architecture, Ms. Cathy Koerner, Deputy Associate Administrator for the Exploration Systems Development Mission Directorate and Dr. Greg Chavers, Director for the Technical Integration Office in NASA's Exploration Systems Development Mission Directorate discussed with the Panel the stand-up of the Architectural Development Office (ADO) and the Technical Integration Office (TIO). These two organizations were established to develop and execute the following mission-level activities:

- To define and maintain the target mission architecture for the Artemis Moon-to-Mars campaign being executed by Ms. Koerner and the ADO.
- To define top-level requirements, identify core conceptual capabilities and potential gaps, and then align Science and Technology investments to fill those gaps, as executed by Dr. Chavers and the TIO.

Both organizations have hit the ground running and the Panel is pleased to see that an initial architecture review is scheduled for the first quarter of calendar year 2023, which will be followed by recurring annual reviews supported by focused analytical studies and assessments. Mr. Bray indicated that this repeatable cycle is important to enable evolution of the architecture and to also maintain architecture configuration management across the Agency. He added that there is no doubt these efforts will provide the necessary guidepost for the Moon-to-Mars mission set.

Mr. Bray informed that at the SE&I level, Ms. Erika Alvarez, Acting Advanced Exploration Systems SE&I Director, and her SE&I team continue to deliver on important engineering artifacts that clearly define engineering roles and responsibilities, enable design and development decisions, ensure program element integration, maintain engineering activity alignment, and most importantly, manage technical and safety risk.

Ms. Alvarez provided the Panel with an update on the Artemis Integrated Product List. A couple key points to draw from the discussion include:

- The Artemis Integrated Product List is a comprehensive list of all engineering artifacts that are in progress or have been baselined. Key systems engineering documents that have been baselined include the Risk Management Plan, the Systems Engineering Management Plan, the Schedule Management Plan, the Safety and Mission Assurance Plan, and Configuration and Data Management Plan. Mr. Bray stated that these are all important foundational documents for key processes and to establish clear lines of authority for engineering decision-making and risk acceptance/resolution. It is good to see them baselined and implemented, he added.
- Mr. Bray noted that the team also showed the traceability of the requirements from the mission architecture, via the Human Rating Certification Requirements and Interoperability Standards Requirements documentation, to the SE&I requirements activities, and then all the way down to the system elements. This will certainly deliver a well-integrated system, Mr. Bray affirmed, and it will identify any technical and safety risks as the program progresses. It also enables a bottom-up feedback loop back to the architecture to understand emerging technical risks, trades, and further inform evolution of the architecture at the mission level.
- And as a last point, Mr. Bray stated that processes are now in place to maintain engineering baseline configuration at all levels, and they are interconnected. Continued focus on the Interface Requirements Documents will be important for integration and interoperability going forward. To further enable this, the Agency is implementing a model-based systems engineering approach to create a modeled, single source of truth for the system design. This will be an area that the Panel would like to follow going forward.

Lastly, during the ASAP Third Quarterly Meeting, the Panel discussed with the Artemis team the importance of an integrated master schedule. During the Fourth Quarterly Meeting, the Artemis team showed the Panel the Artemis Mission Schedule. The output product of this tool is reviewed and evaluated monthly and informs leadership and the team of:

- Critical paths and slack erosion.
- Performance metrics and trends.
- Emerging issues and potential disconnects.
- Cross-program interfaces and dependencies.
- Impact of changes to current and subsequent missions.

Mr. Bray assured that these reviews ensure Artemis program alignment with all stakeholders, and they enable quick identification of any program disconnects or changes that could create technical risk. This, combined with the previously discussed architectural and SE&I activities, provides NASA leadership with a comprehensive set of tools, processes, and products to manage, understand, and resolve technical and safety risks early in, and throughout the design process.

In summary, the technical and organizational integration demonstrated during this ASAP Quarterly is exactly what the Panel has emphasized over the last two years as needed in order to successfully deliver on such a highly complex mission system and evolving campaign. Mr. Bray indicated that these architectural and SE&I artifacts, processes, roles, and responsibilities were not evident, or were certainly unclear, 18 months ago; however, they have come together well, and the Agency's integrated approach is much more unambiguous today.

Looking forward, Mr. Bray cautioned, it is important that the right balance of process, transparency, and product delivery continue to be implemented so that there is sufficient engineering rigor that continues to add value, and that the processes do not become encumbered by bureaucracy. Today, the NASA architectural and engineering teams have created the right processes enabled by agile engineering tools to be effective, and the Panel commends the entire NASA team for the work done to date. Keep pressing!

On a final note, the Panel would like to acknowledge the leadership of Mr. Mark Kirasich, Deputy Associate Administrator for Artemis Campaign Development within the Exploration Systems Development Mission Directorate in this area—it has been nothing short of outstanding, Mr. Bray asserted.

Clearly, Dr. Sanders noted, Mr. Jim Free and key members of his organization, including Mr. Kirasich, Ms. Alvarez, and so many others have made great strides in achieving an integrated program from legacy pieces, commercial industry capabilities, and international partnerships, though critical efforts remain. As Mr. Bray noted, the balance between requisite systems engineering discipline and streamlined management is truly important. The Panel is encouraged that clear lines of responsibility and accountability for this need are emerging.

As the Panel proceeds to digest all the insights from the year's fact-finding and insight sessions, and works toward producing the ASAP 2022 Annual Report, the Panel also looks toward its 2023 program of work.

Dr. Sanders then opened the meeting up to comments from the public. No comments were received. She thanked all who joined and adjourned the ASAP Fourth Quarterly Meeting of 2022 at 2:00 p.m. EDT.

ATTACHMENT 1

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

PARTICIPANTS

Allen Wood	NASA
Amanda Miller	Air and Space Forces Magazine
Amy Donahue	NASA Aerospace Safety Panel Member
Ann Zulkosky	Lockheed Martin
Bill Harwood	CBS News
Boeing Houston	Boeing Houston
Brian Harvery	Van Associates
Chad Kreikemeier	Boeing
Codell Macinis	SpaceX
Danny Lentz	NASA Space Flights
Darlene Pokora	NASA Langley
Dee Russell	Boeing
Diana Ozlespy	NASA
Etiewne Eavurgne	European Space Agency
Frank Groen	NASA OSMA
Gosh Merritt	Boeing
Jeff Foust	Space News
Jessica Lang	NASA
Kathryn Hamboleton	NASA
Lauren Seavarook	Boeing
Lewis Groswald	Lockheed Martin
Linda Karanian	Karanian Aerospace Consulting
Lora Bleacher	NASA HQ
Loren Grush	Bloomberg
Marcia Smith	Space Policy Online
Micah Midenberg	Wall Street Journal
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Patrick Forrester	NASA
Rebecca Regan	Boeing
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