NASA ADVISORY COUNCIL

SCIENCE COMMITTEE

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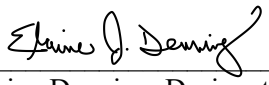
MEETING REPORT

2/21/21

Meenakshi Wadhwa, Chair



2/22/21

Elaine Denning, Designated Federal Officer

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December 1, 2020

Opening Remarks

Ms. Elaine Denning, Executive Secretary of the NASA Advisory Council (NAC) Science Committee (SC), opened the meeting and made some administrative remarks. Ms. Denning introduced Dr. Meenakshi Wadhwa, Chair of the SC, and member introductions were made. Dr. Wadhwa briefly introduced the agenda, highlighted by the launch of the Sentinel-6 Michael Freilich satellite, and the extraordinary success of the Origins, Spectral Interpretation, Resource Identification, and Security-Regolith Explorer (OSIRIS-REx) mission.

NASA Science Overview

Dr. Thomas Zurbuchen, Associate Administrator (AA) of the Science Mission Directorate (SMD), provided an update, beginning with the bad news that the Arecibo radar facility had completely collapsed. The happy news is the successful landing of Chang'e 5 on the lunar surface, a first sample return mission for the Chinese space agency. The entire scientific community is delighted. It remains to be seen how the relevant agencies will share these lunar samples, hopefully through a process that is open and scientific. There is much to discuss, especially topics that are related to COVID-19, and NASA's new emphasis on Diversity and Inclusion with respect to the composition and excellence of NASA teams.

Another item of note was the successful launch, earlier this year, of the European Space Agency (ESA) satellite, Sentinel-6 Michael Freilich that will be doing important work on rising sea levels all over the globe. NASA and the National Ocean and Atmospheric Administration (NOAA) are partners in this mission that will provide spatially distributed data on sea levels, and lend better resolution to their measurement. Earth's sea level increases are accelerating because there is more water, overall, and it also is warmer, which means greater expansion. With the high resolution that Sentinel-6 Michael Freilich provides, predictive information can be obtained for phenomena such as large-scale, low-pressure systems. Dr. Zurbuchen said he would never forget the day he received word that ESA proposed to name Sentinel-6 after Dr. Michael Freilich, former Director of the Earth Science Division (ESD) who now is deceased. Dr. Freilich's family was able to attend the launch, and all of NASA feels that he still is here with us in spirit.

The next notable news is the great success of the Touch-and-Go maneuver in Nightingale Crater, on the asteroid Bennu, by the OSIRIS-REx spacecraft. The good news and the bad news is that the spacecraft obtained so much sample that it was leaking into space. Many mission team members participated in solving the leakage problem, which resulted in maneuvers that were able to stow the sample safely and quickly. In other SMD news, the Stratospheric Observatory for Infrared Astronomy (SOFIA) aircraft has confirmed for the first time the presence of water on the sunlit surface of the Moon, located in Clavius Crater. This was a surprising result, but it added an element of excitement to the study of the Moon. The James Webb Space Telescope (JWST) has completed environmental testing. Dr. Zurbuchen reported having visited the JWST site in November, prompting his gratitude for the mission team's hard work. He added that he would not rest easily until its launch next year.

The Parker Solar Probe completed its sixth perihelion, and while doing so, observed a fast-moving "sungrazer" in September. On the International Space Station (ISS), in Plant Habitat-2, astronauts have been successfully growing radishes, while researchers continue to learn more about long-duration flight and its effects on living things. Aside from providing sustenance, gardening in the space environment also turns out to have positive psychological effects on the crew.

Looking ahead to 2021, Mars 2020 (M2020) Perseverance will land on Mars in February, its key task being to collect samples, but also to operate instruments such as the Mars In-Situ Resource Utilization Experiment (MOXIE) and the helicopter technology demonstration. OSIRIS-REx will depart Bennu and

head back to Earth. The commercial entities Astrobotics and Intuitive Machines, through the Commercial Lunar Payload Services (CLPS) program, will be launching science, as well as Human Exploration and Operations (HEOMD) payloads, to the lunar surface in 2021. If one of these two launches works perfectly, NASA will consider it a success. The Double Asteroid Redirect Test (DART) is scheduled to launch in July 2021, followed by Lucy, a probe to the Trojan asteroids that will perform maneuvers very similar to New Horizon's flyby of a Kuiper Belt object. The next launch will be the Imaging X-ray Polarimetry Explorer (IXPE), an Astrophysics mission that will measure polarization of x-rays for the first time, followed by the launch of JWST. The last are two related missions, Landsat 9 (with the U.S. Geological Survey), and then the Geostationary Earth Observing Satellite (GOES)-T (with NOAA); the latter mission being transformative in improving weather forecasts. In 2022, SMD also will have many missions in multiple disciplines.

Status of SMD flight projects

All SMD missions in formulation are moving forward, with adjustments when necessary. Sentinel-6 Michael Freilich was launched on schedule and within cost, but other missions may well suffer from COVID impacts. Needless to say, SMD will have to consider cancellations and delays as conditions change. Most missions will stay within their cost and schedule, including JUpiter ICy moons Explorer (JUICE), Psyche, M2020, Janus, Mars-moon Exploration with GAmma rays and NEutrons (MEGANE), the X-ray Imaging and Spectroscopy Mission (XRISM), Euclid, Landsat 9, the Polar Radiant Energy in the Far-InfraRed Experiment (PREFIRE), and the Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats (TROPICS) mission. Some missions that have experienced impacts from COVID are Europa Clipper and JWST. In implementing SMD research priorities during the COVID pandemic, NASA has decided to fund extensions in Research and Analysis (R&A) for people who really need it, and also will offer 124 NASA Postdoctoral Program (NPP) fellowships; these decisions will be revisited if supplementary funding is obtained. Virtual panel reviews are working well, and NASA is considering keeping the practice, as it saves time and money. There also have been six virtual site visits that have gone very well.

Regarding the Internal Scientist Funding Model (ISFM), a program that NASA has adopted to better serve its roughly 1,000 civil servant scientists, the Agency continues to focus on the things that these individuals do that are value-added, over and above research. NASA scientists are stewards of NASA mission requirements and success, and also lay the foundation for future missions. NASA decided to implement ISFM in order to make sure the Agency is focused on what is done best at NASA. After three years of ISFM implementation, the Office of the Chief Scientist (OCS) now is conducting an evaluation of the efficacy of ISFM, after which NASA will determine whether or not to go forward with the model. Dr. Zurbuchen's personal feeling was that there have been some successes, and that the ISFM teams have done a good job. NASA views its civil servant scientists as a valuable part of the national community of scientists.

SMD's new *Science Vision 2020-2024* is focused on mission success: safety, inclusion, integrity, safety, teamwork, and excellence. SMD wants to ensure that it provides a safe and inclusive environment for everyone to work in at NASA. The NASA Administrator has specifically added inclusion as NASA's fifth value. Inclusion is harder to define than diversity, but NASA recognizes that its strength is in its people, and inclusion is part of that strength. Having listened to anecdotes from his many colleagues, Dr. Zurbuchen felt that it was quite clear that changes need to be made. SMD has put together an anti-racism action group to look at ways in which SMD and its stakeholders can do better in equity and inclusion, and to make it an enduring philosophy. The action group will examine ideas and outcomes. Engagement across SMD has taken place to identify ideas to implement now, as well as long-term actions and end-state themes. Thus far there have been 40 responses, 35 participants in incubator workshops, as well as emails and discussions, which have generated over 200 ideas. Beginning on December 3, NASA will be hosting a series of internal dialogues with the aim of implementing 8 "quick wins," and will be

establishing a longer-term group on inclusion, diversity, equity, and accessibility (IDEA); there are 40 volunteers for this activity already.

Dr. Tom Herring asked if NASA was going to be involved in rebuilding the Arecibo radar facility. Dr. Zurbuchen noted that while Arecibo is a National Science Foundation (NSF) facility, NASA is trying to identify ways to help people who are employed by Arecibo; other than that NASA will follow NSF's lead. NSF has been very transparent thus far, but no one is sure what they intend to do. Dr. Vinton Cerf offered to ask NSF what they intended to do. Dr. Wadhwa said that to her knowledge, NSF intended to decommission Arecibo. Dr. Zurbuchen thought that the final disposition of Arecibo would relate to NSF's science objectives.

Dr. Pat Patterson asked what the Committee could do to help minimize the impact of COVID on SMD. Dr. Zurbuchen said he had taken the position of "safety first" for the workforce, and that the faster the Agency can get back to building systems efficiently and safely, the better. A Town Hall meeting on the subject of how teams can do engineering safely might be a timely idea. Teams are moving forward, however, and Dr. Zurbuchen said he was not aware of a single on-site infection. There's no one right way to do this; not everything is funding-enabled. Certain things are going to take longer, no matter the circumstances. Dr. Zurbuchen welcomed feedback on how NASA is moving forward. Dr. Cerf said that the National Reconnaissance Organization (NRO) is at 85% capacity on-site, and that it might be useful to chat with the director of the organization, Chris Scolese. Dr. Zurbuchen said he had had the conversation with Scolese, and recognized that many NASA civil servants don't need to be in the office, while some do need to be in the labs. NRO has many lessons learned in this regard that are important. Dr. Amanda Mainzer asked if NASA could lead a cross-agency working group to provide guidance to people who are doing touch-research, given that NASA has done very well in going forward in the COVID environment. Dr. Zurbuchen said there was no working group as such, but he had already coordinated within the Agency, and with NASA contractors. He said he would completely support such a working group, or set up an event, to which NASA could bring its best practices. Dr. Mainzer noted there was much practical advice to be gleaned from the NASA Centers.

Dr. Chick Woodward thanked Dr. Zurbuchen for standing up the IDEA Working Group, and expressed great interest in the outcome. He also suggested that SMD's *Science Vision 2020-2024* document be circulated more widely. With regard to the Chang'e 5 mission landing on the lunar surface, he asked if there were any new avenues for bilateral interactions with Chinese investigators, or a broader international consortium on preserving science in the lunar environment. Dr. Zurbuchen said that NASA continues to be constrained by law from dealing bilaterally with China, and that these laws are based on some legitimate concerns. He would of course prefer that nations share their science data freely, making it a common practice across the board, working toward a model of international peer review. There has been progress in data-sharing in recent years, but multilateral work and collaboration remain a complex discussion. He felt that scientists would continue to cheer for each other regardless of political fault lines; they suffer together and celebrate together.

Dr. Mike Liemohn asked how much proposal pressure is experienced due to ISFM. Is it over- or under-subscribed? Is it generating more ideas from NASA civil servant scientists? Dr. Zurbuchen said that he did not have all the data yet, but expected that in many cases that there is a push and pull. An example is the Goddard Community Coordinated Modeling Center (CCMC): could this be done at a university? Maybe, but preferably not. Once OCS is done with the review, NASA can think about it more. Dr. Michael New commented that the ISFM is not equivalent to an intramural grant competition; it is much more collaborative and interactive, thus talking about proposal pressure is not an applicable concept.

Mr. Marc Weiser noted that NASA now has commercial partners (e.g., through CLPS) that will be responsible for more than they have been before. As additional CLPS missions come on board, are they

sharing post-launch best practices? It would be a shame to lose that information. Dr. Zurbuchen said that HEOMD has created a model that actively transfers knowledge to these companies, and that NASA discusses the very questions Mr. Weiser had posed. Entrepreneurial motivation is a very powerful thing—these companies want to survive. These companies' destinies are aligned with NASA. We all want the same thing, and need to learn from each other. SpaceX is a good example of leadership, but NASA needs to maintain an even playing field across the board. Dr. Zurbuchen said that the Agency always has lessons learned discussions on both the technical and the business practice issues associated with its commercial partners.

Goals of the Meeting

Dr. Wadhwa reviewed the goals of the meeting, which were to focus on Mars Sample Return Internal Review Board (MSR IRB) results, the Heliophysics Environmental and Radiation Measurement Experiment Suite (HERMES) instrument at Gateway and other space weather highlights, the Biological and Physical Sciences Division (BPS) having recently moved from HEOMD to SMD, Division Advisory Committee Chair issues, OSIRIS-REx success, Sentinel-6 Michael Freilich, and an outbrief to the SMD AA.

MSR IRB Report

Dr. David Thompson, Chair of the MSR IRB, presented highlights from the final report. At base, the IRB found that MSR should proceed, as the mission's scientific value is extraordinarily high, and the necessary technology is now available. In addition, the NASA/ESA partnership enhances international cooperation and financial feasibility, while the potential results of this historic deep space program could yield world-changing discoveries. However, the IRB also found that MSR is extremely ambitious and challenging, technically complex, and is a mission that should be conducted with utmost rigor, as with the M2020 and Curiosity missions. M2020 is a rover with caching capability, representing the first step toward sample return from the Mars surface. The two new missions that were the focus of the IRB are the Earth Return Orbiter (ERO) and the Sample Retrieval Lander (SRL). The campaign also includes a Sample Return Facility, which was not part of the IRB scope. In all, there are 12-15 critical events that must take place in order to carry out a successful MSR mission. The first is the landing and deployment of M2020, followed by four more rocket launches, three planetary Entry, Descent and Landing (EDL) events, two Mars rover operations, and one autonomous orbital rendezvous and capture, with first-of-their kind robotic activities. There currently are six to eight NASA Centers involved in the MSR architecture, as well as France, the UK, Italy, ESA, and other partners. The SRL will employ three major surface elements: a Sample Fetch Rover and Sample Fetch Arm (provided by ESA) and the Mars Ascent Vehicle (MAV; NASA). An orbiter will carry the Capture and Containment Retrieval System (CCRS; NASA), made up of the Capture and Containment Module, and the Earth Return Module.

Dr. Thompson briefly reviewed the membership and structure of the IRB. The charter given to the IRB was quite broad: assessing technical and management approaches, science priorities, interfaces between other missions and systems, and schedule and cost assessment, making for a far-reaching study.

Summary of MSR IRB observations and findings

NASA currently is ready to undertake MSR, which was identified as a high-priority mission in the latest Planetary Decadal Survey. The NASA/ESA partnership at the heart of MSR is an important example of long-standing cooperation between these agencies, and over the last several years, NASA and ESA have undertaken a thorough assessment of MSR.

The top six recommendations of the MSR IRB report are:

- Replan the program for SRL and ERO launches in 2028, with the potential of a 2027 launch to continue to be studied.
- Increase the total budget to between $3.8 to $4.4B.

- Maintain the current schedule to Preliminary Design Review (PDR) to minimize technical and schedule risk (regardless of whether launch dates are earlier or later, as per IRB recommendations). However, it is also important to note here that later launch opportunities, 2030 and 2032, are unfavorable for the system being developed today.
- Further explore mission architectural and vehicle options, including consideration of two somewhat smaller landers.
- Simplify Center organizational roles, which the IRB sees as unduly complex.
- Consolidate Headquarters program management of MSR and M2020, and integrate the science and operations of both missions.

The executive summary conclusions of the MSR IRB report are:

- Endorse the NASA/ESA movement to the next phase.
- Due to its ambition and complexity, MSR must be conducted with mission success as its top priority.
- The current baseline, with launches in 2026 and a $3B budget, is not consistent with previous Class A/Category 1 missions.
- The scientific value of MSR is extraordinarily high.
- The NASA/ESA partnership enhances international cooperation and financial feasibility, and the completion of the MSR mission has the potential for world-changing discoveries.

Dr. Jeff Hoffman asked what the consequence would be of trying to maintain a 2026 launch schedule. Dr. Thompson responded that over the next year or so, there would not be much of a difference, but beyond that time, any design decisions that are driven by schedule have historically been problematic. In the past, launch date slips have resulted in considerable re-design. Dr. Hoffman noted that there has been discussion of having the M2020 Perseverance rover placed near the designated sample retrieval site. Dr. Thompson said that in either case (2026 or 2028), it was hoped that Perseverance would be capable enough to contribute to sample caching in convenient places; however, precision landing techniques are expected to have improved by that time. Dr. Woodward asked if a later launch date would help systems that are currently at lower technology readiness levels (TRLs). Dr. Thompson noted that the critical path for the orbiter is the CCRS, and the critical path for the lander is the design (the propulsion system and structures will be all new). Everything has to go perfectly for everything to be ready in 2026. Dr. Hoffman expressed some concern about the implications of an extra billion dollars being extracted from the SMD budget.

Dr. Cerf asked if there were a possibility for more than one return, or a possibility for an orbiter at Mars that can be used more than once for sample transfer. Dr. Thompson said the IRB did discuss "safe havens" for sample caches: do we launch all the samples in the MAV, or do we keep some on the surface for a later attempt in the event of a failure of transfer? Communications are also an important factor; the MAV launcher will be tracked both optically and with a radio beacon. The IRB also discussed repositioning the MRO to effectively extend the workday on Mars, which could boost productivity of sample collection by 15-20%. Mr. Gramling noted that the ERO also will provide relay capabilities, lending another aspect of resiliency to the MSR mission; the orbiter containing the sample is designed to be stable in Mars orbit for ten years.

The full MSR IRB report, containing 44 specific findings, can be found at https://www.nasa.gov/sites/default/files/atoms/files/nasa_esa_mars_sample_return_irb_report.pdf

Public Comment Period
No comments were noted.

Sentinel-6 Michael Freilich

Dr. Karen St. Germain introduced a science briefing on the Sentinel-6 Michael Freilich mission. The mission represents a partnership with several European space agencies, which over the years, and especially thanks to Dr. Freilich, have developed a strong and trusted partnership. This is the first NASA/ESA joint mission in Earth science, and the first time the European Union Copernicus program had invited NASA to join in such a mission. The new satellite builds on a 30-year heritage of ocean altimetry missions, and paves the way for next-generation Earth science international missions. Dr. St. Germain noted that she was a graduate student when the first ocean altimetry flew, and in her work she had contributed to altimetry calibration and validation activities, thus, she found this opportunity especially meaningful. The NASA Earth Science fleet has much international partner participation, which brings an enormous return on investment on the science, and the deployment of capabilities themselves. She said that Dr. Freilich's son, daughter and grandchild were able to attend the launch, which was a moving event for many reasons. The late Dr. Freilich was a force of nature for Earth science, and for the promulgation of international partnerships. The SpaceX launch was quite spectacular.

Dr. Nadya Vinogradova Shiffer presented the science highlights for Sentinel-6 Michael Freilich, whose prime mission is to measure sea surface height from space and to maintain a continuous, highly accurate record of sea surface rise over the globe. The mission will contribute to both a global planetary view of the oceans, and will provide local views of areas of interest. Besides monitoring changing sea levels, the mission will improve the understanding of the physics of sea level change, and thus improve predictive models. The length of a continuous, unbroken climate record matters. Science is now in a position to catch the secular trend of human effects on sea level rise. The original purpose of ocean altimetry was to measure ocean circulatory patterns. Knowing how the ocean moves also yields knowledge about how the ocean transfers heat, carbon, and oxygen, as well as insights into smaller phenomena such as oil spills. These data are also valuable for weather and atmospheric modeling. The height of the ocean column integrates the process from bottom to top, and altimetry will pick up the signal at the surface. Combined with data from other assets such as the Global Precipitation Measurement (GPM) mission, the Earth Science satellite constellation will improve the understanding of hurricane evolution. Sentinel-6 Michael Freilich will provide dozens of profiles per day of the atmospheric state.

Dr. Herring asked if the radio-occultation abilities on Sentinel-6 Michael Freilich were better than average. Dr. Vinogradova Shiffer said that the signal-to-noise ratio of Sentinel-6 Michael Freilich will be several orders of magnitude better than previous radio-occultation sensor schemes. Dr. Cerf asked if the UK would be forming an agency distinct from ESA, given its impending exit from the EU. Dr. St. Germain said that to her knowledge, this was not certain. Dr. Cerf asked if all of the data had been preserved, and in the proper format, from this 30-year record of altimetry. Dr. Vinogradova Shiffer noted that all of the data are recorded and distributed in NASA platforms, in terms of both data and algorithms, and are freely available to the community. Dr. Herring observed that when such data does get reprocessed, it is very valuable. Dr. St. Germain added that the real power of these observations emerge when they are compared with observations from other platforms and sensors, which enables us to use the "system of systems" to observe the very interconnected Earth system.

ESAC Report

Dr. Herring presented the latest results from the Earth Science Advisory Committee (ESAC), whose last meeting on October 22 was devoted entirely to the annual Government Performance Reporting Act Modernization Act (GPRAMA) exercise, assessing Earth Science Division (ESD) goals 1.1.8, and 1.1.9 and voting on how ably ESD met these goals. ESD was judged to be fully meeting expectations, with no issues noted by the ESAC. ESD focus areas assessed during this exercise were atmospheric composition, carbon cycle and ecosystems, climate variability and change, Earth surface and interior, water and energy cycle, and weather and atmospheric dynamics.

Dr. Herring highlighted one important aspect of ESD's response to the COVID crisis. On the COVID-19 Earth Observing Dashboard, one can easily see the effects of the COVID lockdown in terms of economic, agricultural and environmental indicators (https://earthdata.nasa.gov/covid19/). Dr. Wadhwa asked if there were any issues ESAC discussed with regard to the lockdown policies associated with the pandemic. Dr. Herring said that the sense was that people are coping extremely well; NASA facilities have been very good at maintaining social distance, and keeping missions going.

HPAC Report

Dr. Liemohn gave an update on the latest Heliophysics Advisory Committee (HPAC) results, having held a teleconference on September 21 to cover its GPRAMA obligations. HPAC's next meeting is to be determined due to a large change in membership; it is hoped that the Committee will be up and running soon. Dr. Liemohn presented one major heliophysics science highlight from the Acceleration, Reconnection, Turbulence and Electrodynamics of the Moon's Interaction with the Sun (ARTEMIS) mission, to be distinguished from the 2024 lunar Artemis landing. ARTEMIS is comprised of twin satellites that orbit the Moon and measure the electric potential difference in the wake of the solar wind behind the Moon. These results provide research implications for plasma flow around other celestial bodies.

Mr. Weiser asked if there were there opportunities with the Artemis lunar mission to re-focus on science, such as the design of the HERMES package. Dr. Liemohn affirmed that this was the case. Dr. Woodward asked if Dr. Liemohn had any comments on participating in the newly interdivisional nature of the SMD GPRAMA exercises. Dr. Liemohn thought it went well, and that the exercise had precipitated good discussions.

HPD Space Weather Update

Dr. Nicola Fox, Director of the Heliophysics Division (HPD), gave an update on the HPD space weather portfolio. HPD is NASA's principal research arm of space weather, partnered with NOAA, DOD, USGS, the U.S. Naval Research Laboratory, and U.S. Air Force Laboratory. In October, the Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow Act (PROSWIFT) Act was signed, which codifies ongoing efforts across the government, and which the FY21 budget enables for immediate implementation. The budget provided will allow NASA to do what it does best, and to advance NASA's space weather capability. HPD has developed a NASA Space Weather Strategy vision: to advance the science of space weather to empower a technological society safely thriving on Earth and expanding into space, and is now in the process of creating an Implementation Plan. Current space weather activities already under way include:

- strengthening NASA's partnership with ESA and other international and interagency partners to ensure maintained operations of space weather monitoring satellites still in operations;
- planning for space weather monitoring capability on future NASA missions, including the Geospace Dynamics Constellation;
- working with other federal agencies including NOAA and DOD to build new space-based monitoring missions, to ensure the government has backup capability to sufficiently maintain space weather forecasts;
- carrying out basic research in solar and space physics, and space weather, including a number of joint interagency research and modeling solicitations with NSF and NOAA;
- developing a robust partnership with NOAA, NSF, and DOD to establish an interagency framework for supporting the transition of federally funded space weather research into operational and applied use, and to ensure that data support the direction of NASA-sponsored research; and,
- supporting competitively awarded grants for the purpose of advancing solar and space physics and space weather research-to-operations.

The Division now is planning for space weather monitoring capabilities on all new Heliophysics missions.

Dr. Jim Spann addressed some of the research and partnering with NOAA. NASA HPD partners with the R&A and modeling efforts of NSF and NOAA, and has held many joint solicitations through this tri-agency partnership. NASA also works closely with DOD, given their need for operational data in space weather. HPD is currently rolling out a framework for supporting the transition of federally-funded space weather research into operational environments by supporting grants, and the multidisciplinary DRIVE centers, which also will help NASA and its partners advance the science of space weather. The new Space Weather Science Application Team (SWAT) is a continuation of the Headquarters team that developed the NASA Space Weather Strategy. SWAT has been augmented to include NASA field centers that have relevance to space weather. NASA also is in the process of establishing a Space Weather Council, an effort that has received more than 100 interest forms for membership. HPD is in the process of identifying members for the Council.

HPD is in deep discussion with ESA, which is planning a space weather mission to Lagrange Point 5 (L5), and also with the Canadian Space Agency's (CSA's) proposed Arctic Observing Mission over the Northern Hemisphere, which will serve as a tool for both meteorology and space weather. NASA could potentially provide a space weather package to this latter opportunity. The biggest international effort currently underway is with the NASA Artemis program, specifically with Gateway, which will be in a polar orbit around the Moon, providing a unique opportunity to study one of the Artemis science objectives. HPD can take advantage of Artemis Science Objective 3, interpreting the impact history of the Earth-Moon system. HPD has identified ways to conduct relevant science and research that is unique to Gateway's deep-space location, including studying the ambient plasma environment outside of the Earth's magnetosphere as a proxy for deep space, and providing operational space weather data at the Gateway, to help protect astronauts. Gateway can also enable a number of heliophysics investigations, including placing a necklace of satellites around the Sun to image it.

Dr. Jamie Favors addressed the HERMES payload at Gateway, comprised of four instruments: two spectrometers, one magnetometer, and an energetic particle detector. The HERMES mission will focus on tangible science, including determining the mechanisms of solar wind mass and energy transport, characterizing the energy, topology, and ion composition in the deep magnetotail, and establishing a pathfinder for an on-board payload that measures local space weather to support deep-space and long-term human exploration. HPD has just released a two-step Interdisciplinary Science Team call for HERMES, with the first step proposals due in January 2021. HPD has also released a Request for Information (RFI) focused on space weather instruments, to see what the community has in terms of interest, instruments and concepts. The RFI prompted a total of 54 submissions, a mix of concepts, destinations, and instrument types.

Dr. Fox concluded the briefing with commentary on HPD's current position. PROSWIFT has energized HPD to capitalize on its unique abilities to study the Sun, and to play a critical role in HEOMD's Artemis mission, which has recognized the opportunity by placing HERMES in a new position on Gateway. Dr. Woodward asked if NASA would continue to maintain the science as the PROSWIFT program is being implemented, as there is tension between operations and science. Dr. Fox said that HPD is looking at how it can support space weather with real-time data, while continuing its pursuit of ground-breaking science. In HPD's discussions with ESA's L5 mission (an operational mission), Dr. Fox noted that NASA intends to contribute a ground-breaking science instrument, while providing useful operational data for L5. In short, HPD intends to support operations while not impacting its ability to do great science.

Dr. Cerf asked if the Daniel K. Inouye Telescope contributed to space weather. Dr. Fox said that DKIST will provide the highest resolution imagery of the solar surface, which in turn can support other assets

observing the Sun. Dr. Cerf asked if it were possible to predict a Carrington event. Dr. Fox said that NASA and its partners are in a better position to predict such events than in the past, but these capabilities are predicated on knowing which way the magnetic field is oriented, which is not always immediately evident. There are, however, some surface signatures that are somewhat predictive of Coronal Mass Ejections (CMEs). In 2012, there was a large CME that would have been a Carrington-level event, but it was directed away from the Earth.

Dr. Mainzer asked how the emerging solar cycle might impact the Artemis lunar program. Dr. Fox said that it actually is better to launch during a waxing solar cycle, and with regard to CMEs, there is generally a day or two to prepare. There is a large CME heading toward Parker Solar Probe, which will provide the opportunity for a lot of data. Dr. Wadhwa asked if HPD had any plans for the next Decadal Survey. Dr. Fox said that the next one will include both NOAA and NSF, and she expected it would have a space weather component, as well as embedded heliophysics science recommendations.

Discussion

The SC discussed emerging issues from the day's briefings. Dr. Hoffman raised the issue of the MSR IRB's call for increasing the budget, and wanted to elicit Dr. Zurbuchen's view. Dr. Cerf thought NASA had been making remarkable progress during the pandemic. Dr. Wadhwa noted it was definitely worth drawing out NASA's lessons learned on dealing with COVID. Dr. Cerf commented that the pandemic lockdowns have highlighted the fact that people can indeed work from home, and pointed up the importance of heightened cybersecurity (two-factor authentication, end-to-end encryption). Dr. Herring was impressed by how Sentinel-6 Michael Freilich will provide continuity of observations, importantly, as well as a better view of coastlines. Dr. Mainzer noted the impressive collection of applied science from both ESD and HPD. Dr. Woodward said he was curious to discover what Dr. Zurbuchen means by the phrase "acceptable level of risk" in terms of budgetary stress. Dr. Wadhwa said she also had made some notes about the budgetary impacts of COVID, and wanted to learn more details about how NASA is augmenting grants. Dr. Patterson expressed support for a NASA Town Hall that could provide lessons learned on COVID. Mr. Weiser observed that at the end of the most recent government shutdown, Dr. Zurbuchen held an excellent town hall meeting to hear from the scientific community; similarly, the scientific community should be queried for their thoughts on minimizing the impact of COVID. Impacts will be felt for several years, and how to move forward will need to be discussed. Dr. Liemohn thought that Dr. New's comment on the ISFM not being a "grant competition," was interesting, and felt that NASA actually should encourage proposal pressure in the ISFM to weigh priorities and push innovation. He suggested a more detailed briefing from Dr. New. Dr. New reiterated that ISFM is not meant to replace competed research, and that there are areas of research that everyone acknowledges must be done, but would never make it through peer review. The types of research he referred to were not considered cutting-edge or exciting but still were important to do such as interpret other data, for instance, or carry out other research that is important to NASA in some way. This is the underlying motivation for setting up ISFM. He added that there are eight criteria that the OCS will be evaluating ISFM against, and that there will be a complete external review, which will provide course corrections or even terminations.

December 2, 2020

Ms. Denning re-opened the meeting. Dr. Wadhwa introduced the first agenda item, a briefing on OSIRIS-REx, and congratulated the team on the spacecraft's very successful sampling maneuver.

OSIRIS-REx

Ms. Heather Enos, Deputy Principal Investigator (DPI) for OSIRIS-REx, presented, noting that her role is shared with Dr. Dante Lauretta during Phase E of the mission. Ms. Enos leads the science operations team and is responsible for getting data to the ground, after which Dr. Dante Lauretta takes the data to the production and analysis phase. OSIRIS-REx was launched in September 2016, and after an Earth-gravity

assist, arrived at Bennu in December 2018. There it began a year of observations to thoroughly characterize the asteroid surface before it collected a sample successfully on October 20, 2020. The primary Level 1 requirement of OSIRIS-REx was to retrieve 60g of regolith. In terms of operations, the mission is supported by a geographically and culturally diverse team of academic, international, and commercial participants. The spacecraft has a very capable instrument payload deck, including a camera built by the University of Arizona that was designed to characterize the surface and support optical navigation. The spacecraft also carries two spectrometers (one from Arizona State University and one from Goddard Space Flight Center), a laser altimeter provided by Canada, and a student instrument from MIT and Harvard. Lockheed Martin provided the spacecraft, and also built the sample caching receptacle and the arm.

Getting the data to the ground entailed a complex number of steps. Ms. Enos emphasized that the mission established a comprehensive baseline, but nonetheless required some reinvention of processes and tools. It was a very integrative process. From the operations perspective, science and engineering were tightly coupled through an iterative process, which took the baseline and defined science data products. The mission also necessitated science observation planning that required much trust and communication, and a well-orchestrated schedule that also devoted a lot of time developing new tools to ensure smooth operations. Ms. Enos emphasized that this was a major area of effort that reduced risks significantly, borne out by the virtually flawless execution of the mission. Data was downlinked and was used to produce maps that identified regions of interest that could be safely accessed and sampled. Ms. Enos gave kudos to the team's graphic artist, who produced February "Valentines" from Bennu as part of NASA Public Engagement efforts. The PolyCam instrument gave a detailed surface image of Bennu, whose surface was dominated by boulders a meter in size or larger that presented obstacles to finding suitable, sample-able material. The biggest surprise was that Bennu was an active asteroid, in that it ejected particles from various sites.

The team came together quickly to design and implement ways to collect data for a sampling site, and went through an extensive characterization period, adding an operational capability called natural feature tracking (NFT). NFT required an "army" of operations team members to get the testing done, and the feature catalogue completed. Ms. Enos displayed images of the final four sampling sites. The Nightingale site ultimately was chosen, and while Osprey served as back-up site. There were many more challenges than anticipated at Nightingale, thus the team rapidly developed software to create a hazard map (in less than 6 months), yielding autonomous hazardous detection to probabilistically assess hazards during the descent to the site. The team was fortunate to have had a healthy spacecraft, well-performing instruments, and a well-functioning team. Ms. Enos thought that the team was the most important factor to mission success. OSIRIS-REx boasts staggering statistics; the mission uploaded and executed over 1.3M commands, without a single on-board execution error. Historically, bad command modes have led to safe modes and schedule slips, thus this statistic should be considered extraordinary.

Dr. Lauretta presented the science results, first displaying the Touch and Go (TAG) sampling location. The TAG location was imaged in three modalities, achieving previously unimaginable precision. As the TAG occurred, the team could see the material lofted and moved; the Nightingale surface appeared to be soft and compliant, which provided an immediate indication of sampling success. At least 35 particles of less than 2cm were visually identified, and the sample amount collected is estimated to be between 258-575g. The mission team calculated that maximum penetration was probably 48.8cm, and that the sampling capsule was below the subsurface of the asteroid for 16 seconds, also indicative of a very successful sampling event. Some material was lost, but direct imaging indicates that there is still about 400g of observable sample, far more than the Level 1 requirement of 60g.

Mr. Weiser congratulated Ms. Enos and Dr. Lauretta on carrying out an amazing mission, and asked them how others might reproduce such a successful outcome. Dr. Lauretta credited the tight coordination of the

team, and interface definitions. Ms. Enos said that it was not only the tools, but the fact that these tools detected any potential glitches very early in the process, in addition to the mission team's well-defined responsibilities.

Dr. Patterson asked if any information was collected about the ejection activity of the asteroid. Dr. Lauretta noted that this indeed had become an incredible scientific opportunity; the ejection events occurred frequently. The mission was able to develop a new navigational system, built a calibration pipeline for science quality data, and built a whole pipeline for orbit determination that let the team to do a trajectory and probe the gravity field structure. The published results are in a special *Journal of Geophysical Research* issue. It still is an open question as to what causes the ejections.

PAC Report

Chair Dr. Amy Mainzer reported on the most recent meeting of the Planetary Science Advisory Committee (PAC), noting the Committee had carried out a one-hour assessment of Planetary GPRAMA objectives just prior to its full November 30 meeting. She had found the one-hour teleconference a little too rushed, but it worked. All three areas evaluated were determined to be Green. As the last meeting was too recent, there are no findings to report as yet. The PAC heard a briefing on Astrobiology, Mars, Planetary R&A and the ISFM program, the Planetary Defense Coordination Office (PDCO), and the various analysis groups (AGs). The other major news for Planetary is that the new decadal survey is now under way, and it will also include Astrobiology and Planetary Defense in its deliberations. A total of 574 white papers were submitted, despite the impact of COVID. There have been five steering committee meetings to date; and NASA awarded funds to support planetary mission concept studies. Programmatic highlights include the official establishment of the Mercury Exploration Assessment Group (MExAG), which is about to hold its first meeting. The AGs now are involved in supporting the Artemis program Science Definition Team (SDT), as PAC considers it very important to maximize the science that can be gleaned from another era of lunar exploration. PAC also heard results from the MSR IRB, and acknowledges that NASA has established a Planetary Data Ecosystem (PDE) to examine data collected and analyzed by the science community.

Aside from the major success of OSIRIS-REx, a recent planetary science achievement is the unambiguous detection of water by the Stratospheric Observatory for Infrared Astronomy (SOFIA) in Clavius Crater, on the sunlit surface of the Moon. This is a notable achievement, considering that the Earth's Sahara Desert is thought to contain 100 times more water than the Moon. On a sad note, the Arecibo radar dish completely collapsed on December 1, rendering moot any discussions the community had been having on how to salvage it. Arecibo was used to make many significant discoveries over the decades, and also was instrumental in broadening access to and inclusivity in the STEM fields. Arecibo's impact on education was profound. Arecibo was one of two operational radar facilities. The other is the 70m Goldstone facility, which just recently came back online after an upgrade. NASA's search for near-Earth objects (NEOs), therefore, will not be significantly affected. Goldstone has a smaller dish that has better pointing capability but is 15 times less sensitive, and has less range, than Arecibo. Dr. Liemohn added that the loss of Arecibo also was a great loss to heliophysics, in that it helped establish and support many careers in the field.

Dr. Mainzer noted that the PAC also discussed R&A selection rates, and was grateful that NASA has been open and transparent about issues being faced. In addition, the Committee discussed the Mars Ice Mapper (MIM) and an attendant SDT, the ISFM, the limited diversity of the Mars Program Office, MSR, and the decadal survey. Dr. Herring asked Dr. Mainzer if she saw any potential for political support for rebuilding Arecibo. Dr. Mainzer said she understood that the damage still is being assessed, and that there is concern about lead polluting an aquifer beneath the dish. In addition, there will need to be understanding of exactly what capabilities were lost with the failure of the facility.

APAC Report

Chair Dr. Chick Woodward presented results from the latest Astrophysics Advisory Committee (APAC) meeting in late October. The APAC added a third day to discuss the status of the discipline. APAC issued a finding recognizing that both SMD and APD are pivoting to address inequities and barriers across the portfolio to engagement of the black, indigenous and people of color (BIPOC) community. The PAC also highlighted the fact that inclusion now is a clearly stated prime Agency goal. APAC also wrote a finding on the innovative NASA suborbital balloon program, noting its support for general guest investigator participation. APAC also notes that advances in aerostat technologies and other long-duration balloon projects contribute significantly to Astrophysics science. APAC also made a finding on EM spectrum, orbital platform and debris clutter affecting the scientific study of the lunar environment, therefore recommending that APD initiate a discussion within SMD and Headquarters to ensure best-practice planetary protection protocols are developed to enable beneficial shared-use of the lunar environment.

APAC commended APD for its efforts in sustaining and protecting research initiatives and projects during the pandemic, especially those related to early career, soft-money, and other vulnerable groups. APAC recommended that APD gather up lessons learned on COVID, and review these for future deployment. APAC also carried out the GPRAMA process on Performance Goals 1.1.2 and 1.14, and voted them Green. APAC's final letter has been compiled and sent to the Division Director.

Dr. Woodward presented a science highlight on the "Great Dimming" of the star Betelgeuse. The Hubble Space Telescope (HST), SOFIA, and the Solar TErrestrial RElations Observatory (STEREO) were able to observe Betelgeuse through this phase of diminution. Eventually it was concluded that a dust cloud, secondary to a loss of mass, caused the dimming. The observation underscored the importance of cross-divisional synergies. Another highlight concerned the potential characterization of the TRAPPIST-1e exoplanet atmospheres that can be performed by the James Webb Space Telescope (JWST) when it commences science operations. Researchers are using models to try to understand the impact of clouds and hazes on exoplanets, in terms of making the proper measurements and understanding them. Lastly, the capture of a black hole stimulating stellar formation from large distances was performed by Chandra. The spacecraft observed that a black hole, through its large kinetic energy, could stimulate star birth in more than one galaxy at a time, through the ejection of hot gasses.

Science Activation Program

Dr. Wadhwa recused herself for the Science Activation presentation, leaving Dr. Woodward to introduce Ms. Kristen Erickson, Director of the Science Activation Program (SciAct). Ms. Erickson first echoed the grief of the Committee over the loss of Arecibo, and then introduced details of the Science Activation 2.0 Program (years 6-10). The program held four virtual panels over the summer, and selected 9 new awards at $7M a year, for a 28% selection rate. Half of the existing awards have been recommended for full extension; the other half for either partial extension or phaseout. Decisions and selections were informed by the 2019 NASEM Board on Science Education (BOSE) Assessment, 2020-2024: A Vision for Scientific Excellence, the CoSTEM 2018 Plan, and diversity and inclusion efforts. SciAct is funded at $46M per year; this is considered a flat budget.

The rebaselining of Science Activation 2.0 is on track, and will begin in January 2021. The 2019 Science Activation Reach Map indicates that NASA SciAct now is active in all 50 states. In 2020, the map looks essentially the same due to the pandemic. The Solar System Ambassador program (1000 individuals, 50,000 events over the last 5 years) was able to pivot to virtual events very well after COVID struck. The long-term vision for Science Activation 2.0 is to increase learners' active participation in the advancement of knowledge, by 2025.

The NASEM report on the efficacy of the Science Activation Program produced 15 conclusions and 7½ recommendations, but overall the report validated the current model. In Summer 2020, SciAct put panels

together to address the gaps and recommendations identified by the report. Ms. Erickson commended her Deputy for SciAct, Dr. Lin Chambers for running the many virtual meetings. Peer review participants included NAS members, discipline scientists in NASA science and engineering themes, graduate students, educators, and NASA employees. ROSES-20 included a call to inject new ideas into Science Activation and to fill gaps for the next phase of the Program. Specific focus areas were subject matter expert (SME) Engagement, and Broadening Participation. Nine out of 32 submissions were awarded. A Universal Design for Learning model has been adopted for the program, however SciAct recognizes that it still must strive to increase inclusivity in the program. Thus in Science Activation 2.0, the community can expect to see much more intentionality for inclusion.

New awards for SciAct are:

- NASA's Neurodiversity Network (N3): Creating Inclusive Informal Learning Opportunities Across the Spectrum: Lynn Cominsky, Sonoma State University
- NASA SMD Community of Practice for Education (SCoPE): Meenakshi (Mini) Wadhwa, Arizona State University
- The NASA Community College Network: Simon Steel, SETI Institute
- Cosmic Storytelling with NASA Data: Tools for Exploring Data Science: Alyssa Goodman, President and Fellows of Harvard College
- The Eclipse Soundscapes: Citizen Science Project: Henry Winter, ARISA Lab L.L.C.
- SciAct STEM Ecosystems to Broaden Participation in Authentic STEM Learning: Connecting Subject Matter Experts, Communities, and Learners of All Ages ("SciAct STEM Ecosystems"): Rae Ostman, Arizona State University
- STEM Pathways for Native Americans: Bridging Native Knowledge of Earth and Sky with Traditional STEM Programming through the "Native Earth | Native Sky" Program: Kathryn Gardner-Vandy, Oklahoma State University
- Student Airborne Science Activation for MSI (SASA): Charles Gatebe, Ames Research Center
- Planetary Resources and Content Heroes (ReaCH): Andy Shaner, Universities Space Research Association

In support of NASEM Recommendation 3, SciAct has hired two Distinguished Albert Einstein Fellows to support educators and practitioners in SciAct 2.0, and has selected PI Maria Zuber and the MIT Media Laboratory to support development of a coordinated learning network and to provide digital learning support. In Citizen Science, SEPD has extended its virtual workshops (which attract 200-250 participants every week) by 18 months, and has provided ROSES 20 seed funding to scientists. The ROSES 20 proposals are due December 10. The SciAct website has listings of all new and extended awards (https://science.nasa.gov/learners).

Ms. Erickson reviewed budgetary comparisons between SciAct 1.0 and SciAct 2.0; the discipline areas are roughly the same, as well as cross-divisional themes (e.g., museums, etc.). The NASEM report felt that top-level objectives were too broad, thus, SciAct worked to define mid-level objectives (MLOs), and is now working to identify measures of success for these objectives. Participants will be asked to identify at least two mid-level objectives in their projects. Next steps include an Office of STEM Engagement internal PI meeting that was taking place at the present time, and the program also is working to fund extensions and new awards. There is a new independent portfolio evaluator and SciAct 2.0 will hold a kick-off meeting during the week of January 25. Also in 2021, SciAct will participate in ROSES-21, probably focusing on eclipses, and will hold a "Senior Review" process for infrastructure teams.

Dr. Woodward asked who would do the outcome assessments of MLOs. Dr. Erickson said that the SciAct Program would use independent evaluators, and afterward will request that NASEM re-assess the program in another two to three years, in order to maintain the rigor of the program. Mr. Weiser asked

whether NASA could leverage STEM engagement through the set of new relationships it has through CLPS. Ms. Erickson deemed this an exciting idea, but felt it would require a more thoughtful approach, as CLPS involves purchased services.

Biological and Physical Sciences

SMD now is the Directorate for the Biological and Physical Sciences Division (BPS), once a part of HEOMD where it was known as the Space Life and Physical Sciences Research and Applications (SLPSRA) Division.

Dr. Gale Allen introduced the role of the American Society for Gravitational and Space Research (ASGSR) and its role as an Analysis Group for BPS, particularly in decadal survey planning. ASGSR fosters research education and professional development. Dr. Allen is the Executive Director of ASGSR, and Dr. Jamie Foster will serve as President for the year 2021. The Society will be leading the decadal survey effort. ASGSR advocates on the Hill every spring for BPS research, and publishes a peer-reviewed e-journal, *Gravitational and Space Research*, currently undergoing indexing. ASGSR also has established the STEAM Foundation, classified as a 501(c) (3) so that it can solicit tax-deductible donations. Currently the Society has provided two awards for student Ken Souza (with Blue Origin) and Thora Halstead (in collaboration with the Halstead family), and has also started a funded innovation award in collaboration with Axiom; the first award will be made in 2021. ASGSR held its 36th annual conference, virtually, on November 5-6, for which it received 287 member submissions. The conference featured 125 virtual talks, 62 "lightning" presentations, and an art competition.

ASGSR is holding a decadal survey workshop series with Know Innovation, an entity with experience in holding virtual Topical Town Halls. The workshops have pre-recorded knowledge talks, as well pre-recorded "Plus10" videos on future science designed to help identify research gaps. Topics will include inclusion and diversity, as well as animal-based research, plant-based research, fluid physics, and other topics. Registration at the Virtual Topical Town Halls has been healthy; participation is divided at roughly 50/50 between biology and physical sciences, demonstrating an increasing interest in physical sciences. The goal of the Town Halls is to narrow down major research campaign ideas. Dr. Allen encouraged the SC to consult the website at https://asgsr.org/decadal-talks/. There have been 2000 sign-ups for the Town Halls, which is logging about 50% participation. After the Town Halls, the goal is to combine individual ideas into research campaigns. All notes are in Google Docs, and an effort has begun to group these ideas for interactive MicroLabs, to be held in January, which will try to identify people who will champion and lead papers for the decadal survey.

Dr. Sharmila Bhattacharya presented some highlights of Space Biology research in BPS. The overall objectives are to: discover how biological systems respond to the space environment; identify fundamental mechanisms and develop physiological models for biological systems in space; conduct world-class research and develop cutting-edge biological technologies; provide mechanistic understanding to support human health in space; promote open science through the GeneLab Data System and Life Science Data Archive; and support the transfer of knowledge of space-based research to benefit life on Earth. BPS's recent move to within SMD presents an opportunity to find overlaps between planetary protection research, astrobiology, and space biology. There are instruments, research tools, and methodologies that can be shared in these discipline areas; the most recent ROSES call reflects this overlap. Space Biology research includes vertebrate and invertebrate, plant, and microbial research. Two recent papers of note describe the development of a partial weight-bearing model to study the effects of partial gravity on the Moon and Mars, and the use of dried plums in preventing bone loss in a spaceflight analog study on mice. An experiment on the microbiological and nutritional analysis of lettuce crops grown on the International Space Station (ISS) also found that astronauts enjoy the interaction with crops. In October, the Spectrum Multi-Spectral Fluorescence Imager imaging system, designed to capture *in vivo* genetic expression, was launched to ISS. The imaging system can be used on unicellular organisms

as well as plants. Recent studies also have shown details of the interplay between the microbial communities aboard the ISS, and the crew microbiome; and a paper on the human pathogen, *Aspergillus fumigatus*, revealed some biological mechanisms that appear to support increased pathogen resistance to UV radiation. GeneLab database has 284 data sets, allowing scientists to freely access information (of which there is over 130TB of data) on spaceflight experiments. GeneLab has attracted interest from both domestic and international scientists, which has led to a discussion on furthering standards development.

Dr. Francis Chiaramonte presented highlights of the Physical Sciences Research Program (PSRP), which includes the subparts of: Biophysics, Combustion Science, Fluid Physics, Fundamental Physics, Materials Science, and Complex Fluids. This program has ties to both HEOMD and SMD. PSRP uses both flight and ground research. Flight research calls are intermittent, largely due to their cost. Analogous to GeneLab, however, is Physical Sciences Information (PSI) ground research, which holds regular calls. Two solicitations are out right now, one of which focuses on cryogenic tank transfers in space. As the commercial Low-Earth Orbit (LEO) industry takes shape, PSRP also is discussing future flight opportunities with commercial space companies. Preliminary concepts under consideration for lunar surface science include: creation of lunar regolith concrete samples in the lunar environment; material flammability at lunar- and Martian-*g* levels for spacecraft materials; and conversion of water-ice on the Moon for consumables and cryogenic propellants. Some recent highlights from the ISS are an experiment on sintering in space, Gravitational Effects on Distortion in Sintering (GEDS). Another is a thermophysical properties collaboration with the Japanese Space Agency, JAXA; U.S. experiments have begun on a JAXA Electrostatic Levitation Furnace (ELF), testing a variety of materials. Another partnership is under way on biofilms, which is a collaboration with Life Sciences. Preliminary observations on the formation of biofilms in space have found differences in turbidity between terrestrial and space samples, and that biofilms formed in microgravity tend to have lower mass and lower thickness than Earth controls. This study has implications for biofilm prevention on Earth. ISS experiments using the ACME Burning Rate Emulator (BRE) have resulted in immense implications for spacecraft fire safety. An Advanced Colloids Experiment with a Microscope-M2R has applications for creating stabilizer aimed at extending the shelf life of terrestrial products. The sample featured in the presentation with images from 2014 and 2019 stayed on orbit for five years. All experiments were completed without leaks or failures, and analysis of these experiments are still under way. PSI has 1200 users; there are currently 140 proposals and 72 experiments in the database. Of particular note, PSI produced a Cahn Prize Best Paper award in 2018.

Dr. Brad Carpenter presented on Fundamental Physics in BPS, the objectives of which are to investigate fundamental laws of physics and physical processes. Research themes and mission concepts that will go into the decadal survey include the Cold Atom Laboratory (CAL), Deep Space Quantum Link, Earth Orbiting Optical Clock, Quantum Testing of Equivalence and Space Time, and Dusty Plasma Physics. Some of these concepts have had some support in past decadal surveys, and the hope is to mature the science.

CAL objectives are to study scalar and spinor Bose-Einstein condensates, quantum memories, atom interference, and to achieve pico-K temperatures, among several other goals. CAL is the first of its kind, slated for launch to ISS by 2026, with the help of partnerships with NSF and others. BPS will need to increase throughput, however, in order to have NSF participate with CAL. The CAL team recently has demonstrated the design for the first atom interferometer in space, and a paper describing the initial checkout of the system was recently published in *Nature*. Dr. Patterson commented that the Air Force Research Lab (AFRL) is doing work in this area, and asked if the fundamental physics branch has had the opportunity to work with them. Dr. Carpenter thought that AFRL work in this area mostly was in the classified realm. Dr. Patterson noted that some of their work at Kirtland Air Force Base is not classified at all.

Dr. Kevin Sato, Program Scientist for Exploration, presented on Lunar Science in BPS. Integrated lunar science research entails not only fundamental science, but applications knowledge that can feed forward to human exploration. Lunar Science supports studies that contribute to fundamental science knowledge, lunar habitation sustainability, and Mars-forward transit and surface exploration.

There are multiple ways to conduct science at the Moon, but only one way to bring results back to Earth. Currently, only Orion can return science specimens. NASA will have to develop platforms that can perform autonomous research in order to carry out experiments. Lunar Science is currently reviewing a series of experiments for placement onboard Gateway. BPS will be holding Lunar Science workshops in 2021, one for Physical Sciences, and one for Fundamental Physics. BPS Lunar Science also is involved with CLPS lunar science, PRISM solicitation, ISS4Mars, Planetary Protection Roadmap, an Integrated Human Health Roadmap, and beyond-LEO free-flyer platforms.

For Gateway, Lunar Science aims to exploit the enabling environments that are not duplicated at ISS; these environments are characterized by deep space radiation, a lack of atomic oxygen, and lack of magnetic fields, as well as other unknown environmental factors. Lunar Science also seeks to participate in international collaborative research. At the lunar surface, one can study the effects of deep space radiation, lunar albedo radiation, 1/6 *g* at the Moon, no magnetic field, and other unknown factors. Sample concepts of BPS Lunar Science include some materials sciences investigations using Gateway as a site. Other examples of BPS Lunar Science include lunar dust studies to understand the dynamics of dust lofting and charging; impact of combined deep space radiation and reduced gravity on biological systems; and microbiology of the built environment.

Dr. Wadhwa asked the BPS briefing team: as you look forward to the decadal survey, is there anything specific in the Statement of Task that might influence how BPS tackles input? Dr. Allen said that research in these areas has been fragmented, typically, so the effort now is to bring the research areas together, and perhaps couple this with engineering systems (with an eye to supporting humans on the Moon and Mars). Dr. Jeff Hoffman expressed concern about the demand for lunar science, as it will be difficult to set up a laboratory on the Moon. Aside from operations, the lunar science community will need to push for support to build facilities on the Moon. Dr. Sato said that he had heard comments from the community indicating that BPS will help drive this effort, but he recognized that it would be necessary to keep the message going. Dr. Allen added that BPS has a critical role in helping drive human exploration further in space. Dr. Woodward commented that (sample) downmass still is an issue and will be limiting. Dr. Sato agreed, noting that the situation speaks to the need for *in-situ*, autonomous experiments. With Gateway and its international partners, BPS would do well to put forward what it needs in terms of cold stowage, and other conditions.

Discussion/Wrap-Up

Dr. Mainzer commented on the sheer breadth of science that is being accomplished during the pandemic, and thought it was important that the SC recognize SMD for this accomplishment as part of its findings deliberation. In addition, she noted that Dr. Zurbuchen already shares concerns about the risk of increased cost of MSR.

Dr. Woodward said he would consider a finding on diversity and inclusion, and echoed Dr. Mainzer's concerns about MSR, but he said he recognized that Dr. Zurbuchen has a firm hand on the latter issue. He also encouraged a dialogue between APD, SMD and the Agency on the best planetary protection measures that will be necessary to protect the lunar environment. It is important to exploit the new environment in a positive way, and get ahead of any potential for contaminating pristine areas.

Dr. Hoffman said that he was concerned about Artemis and the role of science; there will be a big push in human space flight, and it will be a constant struggle to keep science in its place. He offered to write a finding on the subject.

Dr. Wadhwa suggested a finding on the budgetary recommendations of the MSR IRB.

Mr. Weiser thought for a future meeting, the SC might address post-pandemic engagement of the community in the outyears, to ensure that schedules remain intact. With regard to SciAct as they begin their next phase, he suggested that it might be helpful to them to engage commercial partners in CLPS. Lastly, he commented that OSIRIS-REx's operations statistic (1.3M commands with zero execution errors) is amazing, and that a collection of lessons learned for future autonomous robotic missions will be valuable.

Dr. Liemohn felt that SMD is responding well to the needs of the Artemis program, which might merit recognition from the SC. He further suggested that the SC may have an interest in commenting back to Headquarters on the altered GPRAMA process. Overall, he liked the change, and welcomed the talk across discipline boundaries. Dr. Mainzer seconded the thought.

Dr. Patterson supported Mr. Weiser's suggestion on engaging the community in the post-pandemic timeframe. He remarked on the complexity of MSR. Complexity in itself presents a lot of opportunities for cost and schedule risks to intensify. He also referred to AFRL's non-classified work in quantum physics, optical clocks, and Bose-Einstein condensates, and noted that NASA would benefit from collaborating with them.

Dr. Herring supported a finding on the excellence of OSIRIS-REx software, and also felt it would be critical to say something about Arecibo, and potential overload on Goldstone. Puerto Rico does not have a senator, thus he did not see how Congress could help in this matter.

Dr. Wadhwa and Mr. Weiser teamed to write a finding on SMD's proactive mitigation stance in response to the COVID pandemic. The SC also considered a recommendation that NASA put together a set of charts containing lessons learned on accessing cleanrooms, and other simple, practical guidelines for reducing exposure to COVID. Dr. Woodward undertook to write a finding on SciAct and CLPS.

Outbrief to SMD AA

Dr. Mainzer, in writing a finding about Arecibo, suggested that the SC ask NASA to assess what the impacts the loss will have on planetary science, so that the science community can think about possible gaps that might arise. Dr. Zurbuchen thought it would be good to at least acknowledge the issue. NASA used Arecibo to regain control of one of its solar observatories, for instance. On the other hand, NASA should not overstate the need for Arecibo. He said he had talked about Arecibo at length in public, which might open opportunities to do something. He said he would be ready to engage if NSF decided to rebuild, or build a new facility.

Dr. Wadhwa and SC members apprised Dr. Zurbuchen of other potential SC findings such as: the laudable COVID mitigation strategies at SMD including still retaining goalposts despite cost and schedule impacts; lessons learned from the exemplary OSIRIS-REx performance; diversity and inclusion as an Agency goal (thanks in part to SMD's leadership in bringing the issues forward); and GPRAMA cross-division participation that was appreciated by the Chairs.

Drs. Wadhwa, Hoffman and Woodward raised the potential for a finding on keeping science at the forefront in lunar endeavors, while protecting the lunar environment in terms of contamination, to ensure beneficial shared use of the lunar environment for all stakeholders (orbital debris, electromagnetic

spectrum management, radio pollution from orbiting satellites, etc.) Dr. Zurbuchen felt this finding to be useful and insightful, and requested more specificity.

Dr. Wadhwa and SC members continued noting potential findings such as: ramifications of the MSR IRB recommendation for increased MSR budget; Sentinel-6 Michael Freilich and the importance of continuity; and BPS collaboration, such as cold atom work, and overlaps with AFRL. Dr. Zurbuchen agreed that the BPS finding was useful and that there should be follow-up.

Dr. Wadhwa recused herself briefly, while Dr. Woodward described the SC's proposed finding on SciAct, in that as commercial space more involved some engagement with SciAct should be considered. Dr. Zurbuchen agreed that this was a good comment.

Dr. Wadhwa expressed the SC's appreciation for Dr. Zurbuchen's work during these challenging times. Dr. Zurbuchen credited his team, saying that it was hard to convey just how much work is actually being done. Dr. Wadhwa noted, as a final comment, that it was Ms. Denning's last meeting as Executive Secretary for the Committee, and expressed her appreciation for her tenure.

Dr. Wadhwa adjourned the meeting at 5:36pm.

Appendix A
Meeting Attendees
(Virtual Meeting)

Science Committee Members
Dr. Meenakshi Wadhwa, **Chair,** Arizona State University
Vinton G. Cerf, Google Inc.
Thomas Herring, Massachusetts Institute of Technology *(ESAC Chair designee)*
Jeffrey A. Hoffman, Massachusetts Institute of Technology
Michael W. Liemohn, University of Michigan
Amanda Mainzer, Arizona State University
Pat Patterson, Space Dynamics Laboratory
Marc Weiser, RPM Ventures
Charles Woodward, University of Minnesota
Elaine Denning, **Designated Federal Officer**, NASA Headquarters

NASA Attendees
Kathleen Baynes
Dominic Benford
Sharmila Bhattacharya
Christopher Caisse
Jason Callahan
Bradley Carpenter
Sandra Cauffman
Lin Chambers
David Cheney
Francis Chiaramonte
Laura Delgado-Lopez
Kristen Erickson
Daniel Evans
James Favors
T. Jens Feeley
Galen Fowler
Nicola Fox
Reinhard Friedel
Ellen Gertsen
Lori Glaze
Jeffrey Gramling
Devon Griffin
Jeffrey Grossman
Douglas Gruendel
Shobhana Gupta
Roshanak Hakimzadeh
Hashima Hasan
Jeffrey Hayes
Paul Hertz
Dan Hirsch
Eric Ianson
Lindley Johnson

Jennifer Kearns
Jackie Keshian
Ben Kim
Gilbert Kirkham
Janet Kozyra
Craig Kundrot
William Latter
Christy Layton
Barry Lefer
Margaret Luce
Diane Malarik
Amanda Moore
Melissa Morris
Michael New
William Paterson
Kirsten Petree
Arik Posner
Amy Rice
Stephen Rinehart
Ursula Rick
Alvin Robles
Joan Salute
Kevin Sato
AndrewSchurr
Henry Selkirk
Mary Sladek
Gerald Smith
James Spann
Karen St. Germain
George Tahu
Patricia Thomas
Lucia Tsaoussi
Nadya Vinogradova Shiffer
Thomas Zurbuchen

Webex Attendees
Gale Allen, ASGSR
Ashton Armstrong, ProtoInnovations
Linda Billings, NIA
Francesco Bordi, Aerospace
Stephen Clark, Space Flight Now
Angela Clark-Williams, Electrosoft
Tammy Dickinson, Science Matters Consulting
David Eisenman, JPL
Heather Enos, University of Arizona
Ken Eppens, OrbitGuardians
Sylvie Espinasse, ESA
Jeff Foust, Space News
Joan Higginbotham, Collins Aerospace
Marchel Holle, Space Foundation
Devrie Intriligator, Carmel Research Center

Douglas Isbell, JPL
Bethany Johns, APLU
Linda Karanian, Karanian Consulting
Kelsie Krafton, AAS
Dante Lauretta, University of Arizona
Greg Lee, NGC
James Lochner, USRA
Kristi Manseth, Pacific Research and Evaluation
Robins Mdoka, Constanellis Aerospace, Inc.
Gene Mikulka, Talking Space
Steve Moran, Spire
Kay Nouki
Sabrina Pyles
Ben Reed, IBX
Kurt Retherford, SWRI
Michael Roberts, ISS National Lab
Steven Rider, Pacific Research and Evaluation
Joey Roulette, Reuters
Marcia Smith, spacepolicyonline.com
Dave Thompson, Orbital ATK, retired
Ashlee Wilkins, U.S. House of Representatives
Alexandra Witze, Science News
Joan Zimmermann, Zantech IT, Inc.

Appendix B
Science Committee Membership

Dr. Meenakshi Wadhwa (Chair)
Arizona State University

Dr. Vinton Cerf
Google, Inc.

Dr. Jeffrey Hoffman
Massachusetts Institute of Technology

Dr. Michael Liemohn
University of Michigan

Dr. Amanda Mainzer
Arizona State University

Dr. Pat Patterson
Space Dynamics Laboratory

Mr. Marc Weiser
RPM Ventures

Charles Woodward
University of Minnesota

APPENDIX C
Presentations

1. SMD Science Overview; *Thomas Zurbuchen*
2. Goals of the Meeting; *Meenakshi Wadhwa*
3. Mars Sample Return Internal Review Board; *David Thompson*
4. Sentinel-6 Michael Freilich; *Karen St. Germain, Nadya Vinogradova Shiffer*
5. Earth Science Advisory Committee Report; *Thomas Herring*
6. Heliophysics Advisory Committee Report; *Michael Liemohn*
7. Heliophysics Division: Space Weather Update; *Nicola Fox, James Spann, Jamie Favors*
8. OSIRIS-REx Report; *Heather Enos, Dante Lauretta*
9. Planetary Science Advisory Committee Report; *Amanda Mainzer*
10. Astrophysics Advisory Committee Report; *Charles Woodward*
11. Science Activation Program Update; *Kristen Erickson*
12. Biological and Physical Sciences Division; *Gale Allen, Sharmila Bhattacharya, Francis Chiaramonte, Brad Carpenter, Kevin Sato*

Appendix D
Agenda

Connectivity information is located at the end of this agenda on p. 2.

NASA Advisory Council
Science Committee

December 1-2, 2020

Virtual Meeting

Agenda
(Eastern Time)

Tuesday, December 1

1:00 – 1:10	Opening Remarks / Introduction of Members	Ms. Elaine Denning Dr. Meenakshi Wadhwa
1:10 – 2:10	NASA Science Overview	Dr. Thomas Zurbuchen
2:10 – 2:15	Goals of the Meeting	Dr. Meenakshi Wadhwa
2:15 – 3:00	Mars Sample Return IRB Results	Mr. David Thompson, Chair Dr. Jeffrey Gramling
3:00 – 3:15	***Break***	
3:15 – 3:20	Public Comments	
3:20 – 3:40	Sentinel-6 Michael Freilich	Dr. Karen St. Germain Dr. Nadya Vinogradova Shiffer
3:40 –3:50	Division Advisory Committee (DAC) Chair Reports Earth Science Advisory Committee Heliophysics Advisory Committee	 Dr. Thomas Herring Dr. Michael Liemohn
3:50 – 4:30	HERMES and Space Weather Highlights	Dr. Nicola Fox Dr. James Spann Mr. Jamie Favors
4:30 – 5:00	Wrap-Up Discussion	All

Wednesday, December 2

1:00	Re-Open Meeting	Ms. Elaine Denning Dr. Meenakshi Wadhwa

Connectivity information is located at the end of this agenda on p. 2.

1:00 – 1:45	OSIRIS-REx Sample Acquisition	Ms. Heather Enos Dr. Dante Lauretta
1:45 – 2:15	Division Advisory Committee (DAC) Chair Reports	
	Planetary Science Advisory Committee	Dr. Amy Mainzer
	Astrophysics Advisory Committee	Dr. Charles Woodward
2:15 – 2:55	Science Activation	Ms. Kristen Erickson
2:55 – 3:05	***Break***	
3:05 – 4:20	Biological and Physical Sciences (BPS) Priorities	
	American Society for Gravitational and Space Research (ASGSR) Activities	Dr. Gale Allen
	Space Biology	Dr. Sharmila Bhattacharya
	Physical Sciences	Dr. Francis Chiaramonte
	Fundamental Physics	Dr. Bradley Carpenter
	Lunar Science Opportunities	Dr. Kevin Sato
4:20 – 5:00	Discussion, Findings and Recommendations	All
5:00 – 5:15	Outbrief to SMD AA	Dr. Meenakshi Wadhwa Dr. Thomas Zurbuchen
5:15	***Adjourn***	

Connectivity Information

For SC meeting:

Webex Event connectivity information for each day is provided below. For audio, when you join the Webex event, you may use your computer or provide your phone number to receive a call back, otherwise, call the U.S. toll conference number listed for each day.

On Tuesday, December 1, the event address for attendees is:
https://nasaenterprise.webex.com/nasaenterprise/onstage/g.php?MTID=ec9f04af53099d097214a64cf178fc2ed.
The event number is 199 056 0375 and the event password is wfSEe8uH5*3.
If needed, the U.S. toll conference number is 1-415-527-5035 and access code is 199 056 0375.

On Wednesday, December 2, the event address for attendees is:
https://nasaenterprise.webex.com/nasaenterprise/onstage/g.php?MTID=e51f38c7ac92a01577c5f697d7d1b4c5f.
The event number is 199 748 1916 and the event password is EswGXYZ@742.
If needed, the U.S. toll conference number is 1-415-527-5035 and access code is 199 748 1916.

**** All times are Eastern Time ****