NASA ADVISORY COUNCIL

SCIENCE COMMITTEE

May 21-22, 2019

NASA Headquarters
Washington, DC

MEETING REPORT

M Wadhwa August 20, 2019

Meenakshi Wadhwa, Chair

Elaine Denning August 20, 2019

Elaine Denning, Executive Secretary

Table of Contents

Prepared by Joan M. Zimmermann
Zantech IT, Inc.

May 21, 2019

Opening Remarks/Introduction of Members

Ms. Elaine Denning, Executive Secretary of the NASA Advisory Council (NAC) Science Committee (SC), opened the meeting and made administrative announcements. She introduced Dr. Meenakshi Wadhwa, Chair of the Science Committee, who brought the meeting to order. Members and meeting attendees introduced themselves around the room.

NASA Science Overview

Dr. Thomas Zurbuchen, Associate Administrator (AA) of the Science Mission Directorate (SMD), presented an overview of the Directorate's activities. He provided a number of updates, first on Lunar Reconnaissance Orbiter (LRO) imaging of the impact site on the Moon of the Israeli lander Beresheet. NASA is discussing activities going forward with the Israeli space agency that may have parallels with NASA's Commercial Lunar Payload Services (CLPS), wherein NASA would be able to take advantage of innovative technologies. As with Beresheet, NASA also is contributing a retroreflector to an upcoming Indian Space Research Organisation (ISRO) mission to the Moon. Recent SMD highlights include the detection of the first "Marsquake" by the Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) lander. There has been little seismic activity detected thus far, indicating a potential result. The Jet Propulsion Laboratory (JPL) mission team is still working on getting the InSight hammer moving; the instrument is not part of Level 1 requirements, but it would be nice to have it working. The Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer (OSIRIS-REx) sample-return mission has released new imagery showing boulders strewn across the southern hemisphere of the asteroid Bennu. The mission is preparing to choose landing sites for sample collection. Bennu has been found to be an active body, tossing objects off its southern section. The New Horizons spacecraft captured an image of the Kuiper Belt object, 2014 MU_{69}, now nicknamed Ultima Thule, showing its structure to be an unusual bilobed body thought to be the result of two objects gently merged together. It will take at least another year to download all the data on the object, due to the great distance.

The Parker Solar Probe (PSP) had its second perihelion flyby and is providing amazing data to date on the microphysics of the interaction between Sun and its immediate environment. Dr. Zurbuchen related that "a number of theories are struggling for survival," which he regarded as a signature of success for PSP. A number of journal articles on PSP data are anticipated for late summer or early fall. The Orbiting Carbon Observatory-3 (OCO-3) was delivered to the International Space Station (ISS), where it will continue the study of carbon emissions with a new feature called "snapshot mode," that will produce a "blanket" of measurements over an area of 80 by 80 km. OCO-3 now is in checkout mode, and has broken records for mission time to first light. The Ice, Cloud, and land Elevation Satellite-2, (ICESat-2), launched in September 2018, already is surpassing previous resolution of data for the measurement of ice sheets over Antarctica. The mission recently released bathymetry reference data from the Bikini Atoll, showing new capabilities for understanding the contours of ice sheets at the South Pole. The Transitioning Exoplanet Survey Satellite (TESS) mission confirmed three new exoplanets from July to December 2018, and has identified 398 new candidates for follow-up.

Moon to Mars Plans

Panel 1: Forward to the Moon

Dr. Zurbuchen introduced Mr. Mark Sirangelo, noting his long history in both academia and the space industry. Mr. Sirangelo led a panel discussion on NASA's notional plan to return to the Moon by 2024.

In keeping with the President's Space Policy Directive 1 (SPD-1), NASA has been instructed to "use all means necessary" to return to the Moon in an expedited manner. The target date for return was recently moved from 2028 to 2024. The priority now is to find the most technically feasible way to reach this goal given NASA's current resources. Why go to the Moon? Why spend more money sooner? To establish U.S. leadership; advance technology and capabilities; inspire a new generation in Science, Technology, Engineering and Mathematics (STEM) education; establish leadership in advancing civilization-changing science and technologies; expand U.S. global economic impact; and broaden U.S. industry and international partnerships in deep space. The return to the Moon is also an opportunity to take advantage of the remainder of the lifetime of ISS.

This new push to the Moon has been named the Artemis Program, Artemis being the twin sister of Apollo. The name also reflects the plan to put the first woman on the Moon. The pathway is envisioned as a progression from Earth orbit, to lunar orbit, to the lunar surface, and then to Mars and beyond, each phase of the path feeding forward. Mr. William Gerstenmaier, AA for the Human Exploration and Operations Mission Directorate (HEOMD), commented that the pathway does not represent a linear progression, but a progression that moves backward and forward in a continuum. Dr. Zurbuchen added that NASA will be examining what sort of activities have worked in the near-Earth domain, and what behaviors will get NASA to the next step. Domains and approaches will cut across the Agency.

Phase One of the Artemis Program will entail reaching the South Pole of the Moon by 2024, followed by a Sustainability Phase. A number of strategic changes have been adopted to achieve this goal in 2024. First, NASA will identify a minimum configuration to get there, reducing the crew size to reach the lunar surface from a four-person lander to a two-person lander, plus two in orbit. NASA will make some organizational changes, contracting and hiring differently to accelerate progress. A Presidential budget amendment of $1.6B above the total $21B NASA budget was requested [on May 13, 2019]. Approximately $1B will be used to accelerate the development of human lunar transportation to take astronauts back and forth to the proposed Deep Space Gateway (Gateway), with remaining funding going to the Space Launch System (SLS)/Orion program, and to other technologies to expedite activities. Mr. Gerstenmaier interjected that the Artemis Program is a cross-Agency activity; science will go first, to explore the Moon robotically in advance of humans ($90M), with $123M coming out of the Gateway program for Phase Two.

Dr. Feryal Ozel asked Mr. Gerstenmaier to comment on potential impacts to the SLS/Orion schedule. Mr. Gerstenmaier said the current budget profile maintains the schedule to get to crewed flight in late 2022, which would have been later without the extra infusion. Dr. Wadhwa asked what the budget profile would be to get to 2024. Mr. Sirangelo and Mr. Gerstenmaier indicated that the budget was still in discussion at the White House and at the Office of Management and Budget (OMB). While the initial $1.6B is focused on 2024, other budget discussions will follow; NASA is working through the normal budget process at present. Mr. Sirangelo added that there had been a limited window for the $1.6B amendment that is focused on short-term needs while long-term needs are being determined. Mr. Gerstenmaier said that NASA is also looking for landing systems through commercial avenues, and is having internal discussions about this so more refined budgets can be built going forward. Dr. Zurbuchen noted that this new approach is very different from what NASA has done before in terms of procurement from industry. The funding is not meant for accelerating the CLPS program, it is more for an effort to identify resources and study space weather events to ensure the safety of the astronauts. Dr. Jeffrey Hoffman asked if any of the $132M (for new technologies) was allocated to develop space suits. Mr. Gerstenmaier said that this budget line includes near-term space suits by 2024; these suits will be evolvable.

Mr. Sirangelo continued the briefing. Under the Artemis Program, there will be three missions to the Moon: the first mission un-crewed, the second mission a crewed sortie to lunar orbit, and the third mission to the Gateway and lunar surface. Mr. Gerstenmaier, responding to comments on the human

landing system and the Power Propulsion Element (PPE), said he was not sure that it needed to be three-element program, and that HEOMD is developing a request to industry to come up with possibly a two-element system. Mr. Sirangelo said that Orion and SLS will remain as core capabilities for the Artemis program, and displayed an integrated manifest covering the period 2019-2024. A total of 10-12 launches is anticipated. The Gateway will be essential for the 2024 landing, as it provides a command center and safe harbor for astronauts. It will include a European component. Dr. Zurbuchen noted that lunar science missions to be completed by 2024 will include polar landers and rovers that will study volatiles, understand their distribution, and understand the water cycle, all resulting in data that can be used going forward. The first CLPS missions will not go to the South Pole, but to lunar swirls where surface magnetic measurements can be made. Orbital data will be provided by CubeSats. Mr. Gerstenmaier said that a total of 13 CubeSats are planned for the SLS, most of which will be focused on lunar and deep space.

Ms. Therese Griebel addressed the space technology component of the Artemis program; i.e. an extra $132M for the Space Technology Mission Directorate (STMD), designed to get the first woman to the Moon, construct sustainable habitats, and perform risk reduction activities to get humans to Mars. CubeSats will serve as a pathfinder for the proposed near-rectilinear halo orbit (NRHO) for lunar exploration, as a way to understand navigation needs, as a carrier of synthetic aperture radar (SAR) instruments for lunar surface evaluation, and as communications relays. STMD's new Lunar Surface Innovation Initiative will focus on in-situ resource utilization (ISRU) for water and oxygen extraction on the lunar surface. STMD will also be looking at power generation, operation in extreme environments, and autonomous systems. The Directorate is working with multiple universities on autonomous systems, and is also developing the Solar Electric Propulsion (SEP) element, as it continues the philosophy of using the Moon as a testbed for future Mars exploration.

Mr. Sirangelo said that the Artemis Program will set up a cadence for repeatable operations and maintain presence of the Deep Space Gateway as a jumping-off point, similar to NASA operations at Antarctica, setting up presence in a hostile environment. He briefly displayed the integrated Artemis manifest for 2025-28, where an operational cadence will commence to support commercial activities, using as its core the SLS/Orion systems. Dr. Zurbuchen addressed lunar science after 2024, when a new domain of research will begin at the Gateway that will enable deep-space testing of Mars-forward systems and host science for the improvement of space weather forecasting, for example. Through human presence on the lunar surface, SMD will be able to advance understanding of ISRU, and investigate sample return, in-situ study of impact craters, complex surface instrumentation, and the use of surface telerobotics to support constant science. Mr. Sirangelo noted that the Artemis Program effort enjoys good bipartisan support, and presents an opportunity to do something big.

Discussion

Dr. Wadhwa asked, given the aggressive schedule, what key things are different this time, adding that there also are science opportunities in the lunar program that will need to be prioritized over the next five years. Mr. Sirangelo commented that the program is not entirely new, and that the current acceleration effort is more like a sprint to the finish. NASA has, in fact, been working on the goal of getting humans back to the Moon for the last decade. The new initiative is to push the effort; it's not a new start. Mr. Gerstenmaier noted that the Exploration Mission-1 (EM-1) capsule is being integrated into the SLS, core stages are being actively manufactured, and that HEOMD just has issued a contract for the descent stage. The NASA centers have been working on habitat modules, and NASA is expected to award the PPE contract by this summer. Mr. Sirangelo commented that infrastructure also is well underway. Dr. Zurbuchen noted that the real transition has been in science, which was initiated before the current Administrator took his position. SMD has been looking at lunar science for some time now; the CLPS program is the manifestation of this scientific effort. Dr. Susan Avery asked: what is the level of international collaboration or interest? Mr. Sirangelo noted that a European service module is underway,

and is paving the way for expanding development; the idea is to work the same plan but to work it faster, and most of the international partners were not going to come on-line before 2024 anyway. The international space agencies have limited budgets, and the current U.S. effort will help to increase their confidence in committing to the future. Dr. Avery asked if China was involved in the effort. Mr. Sirangelo said that the U.S. maintains its stance of non-engagement with China. Dr. Zurbuchen noted, that within the limits of the law, NASA does have discussions on science with China, with Congressional approval. China has made some data public from its recent lunar landing that is beneficial to the U.S. SMD plans to keep the discussions going, while fully aligned with U.S. policy and law, and is having discussions with China on Earth science. Dr. Mihir Desai asked how the Artemis Program would deal with delays. Mr. Sirangelo reiterated that lunar exploration does not constitute a single mission, but a program. If a human flight piece gets delayed, there are still CubeSats, robotic rovers, Gateway, etc., in development or in place. Further, NASA is working hard to make the program transcend administrations, by making lunar exploration a national challenge. Mr. Gerstenmaier said that creating a re-usable infrastructure with open architecture and published interoperability standards will make the program resilient to changes in direction.

Dr. Hoffman questioned whether the program might prompt overdesigning for the Moon, presenting a potential caveat against speeding up development. Mr. Gerstenmaier pointed out that the increased delta-v needed for the ability to abort a crewed mission to Earth or to Gateway is actually appropriate for Mars. Mr. Sirangelo commented that an open architecture also helps to upgrade schemes. Dr. Zurbuchen commented that SMD is using a similar strategy for robotic exploration in the Moon to Mars journey. Dr. Vinton Cerf said he was excited about the potential of the program, and asked if NASA was exploring Disruption-Tolerant Networking (DTN) in the context of lunar exploration; a return to the Moon is an opportunity to test DTN and validate protocols. Mr. Gerstenmaier said that DTN will be the standard for interoperability at Gateway.

NASA Science Overview and FY20 Request (continued)

Dr. Zurbuchen and Mr. Craig Tupper continued the overview briefing that included details on the Fiscal Year 2020 (FY20) budget. Mr. Tupper noted that the House of Representatives had posted language that very morning on the budget. Dr. Zurbuchen said that SMD will be continuing a balanced program and implementing the Decadal Surveys. FY20 advances national science and exploration goals through commercial partnerships (such as CLPS), and innovative approaches to promote economic growth; enables Mars Sample Return (MSR) through international and industry partnerships; and prepares for the launch of James Webb Space Telescope (JWST). Progress in CubeSats and other new platforms are popping up faster than expected. The budget is not as high as desired in Planetary Science (given no funding for a Europa lander) and Astrophysics (given no funding for the Wide Field Infrared Space Telescope (WFIRST)). The budget does enable the execution of a robust and innovative Earth Science portfolio, with once again a zero-out of the Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) and Climate Absolute Radiance and Refractivity Observatory Pathfinder (CLARREO-PF) missions. Dr. Zurbuchen commented that Congress is very supportive of the Europa lander concept, and he thought the budget reflected a question of timing. Responding to Dr. Hoffman's comments on landers, Dr. Zurbuchen said he just had visited the Georgia Institute of Technology, which is developing underwater robots that have great relevance to a future Europa lander. NASA will continue to execute innovative partnerships, which will benefit from a diversity of approaches. SMD is pursuing science on future commercial lunar and Mars missions; finalizing pilot contracts to purchase Earth observation data from the private sector; leveraging data and expertise through interagency partnerships, and remaining a preferred partner. SMD has over 400 agreements that comprise nearly 60% of NASA international agreements. SMD also is working to inspire future leaders, achieving excellence through reliance on diverse teams and encouraging new ideas. Another primary focus will be to encourage citizen science competitively, in order to produce publishable data.

Mr. Tupper reported on the cost performance of recent NASA missions. For the last 7 years, SMD missions have come in under budget, on average, by 3%. Dr. Desai asked if there was any pattern of overgrowth for certain programs. Mr. Tupper said he did not see solid evidence of a pattern. He reviewed the NASA Science budget request of FY20 at a total of $6.3B, adding that the most recent House mark-up is 7.16B. The House includes reinstatement of the two Earth Science missions and WFIRST, including the coronagraph, and no additional funding for a Europa lander. However, the current budget does allow for carrying existing lander work through 2020. The House mark-up funds the Heliophysics Division (HPD) at the budget request level. FY20 includes small increases for Earth Science research, Mars exploration and a few other areas. Dr. Zurbuchen commented that the outyears in the budget runout reflect the shift to the lunar campaign.

Dr. Zurbuchen continued that the Planetary Science budget enables an MSR launch as early as 2026 and accelerates launch readiness for the Europa Clipper. In Astrophysics, JWST is proceeding to a 2021 launch. The Spectro-Photometer for the History of the Universe, Epoch of Reionization and Ices Explorer (SPHEREx) is being developed as the next mid-sized Astrophysics Explorer mission. A Senior Review recently terminated the Spitzer telescope, and continued the Stratospheric Observatory for Infrared Astronomy (SOFIA) for a five-year extended mission. In HPD, the Global-scale Observations of the Limb and Disk (GOLD) mission has launched, but the Ionospheric Connection Explorer (ICON) is still on the ground due to difficulty with the launch vehicle, and has been delayed to later in 2019. The Solar Orbiter mission is now scheduled for launch in February 2020. HPD is increasing an emphasis on space weather through collaboration with the National Oceanic and Atmospheric Administration (NOAA). In the Earth Science Division (ESD), funding for the Deep Space Climate Observatory (DSCOVR) and OCO-3 are covered by the FY20 budget, as well as a new incubator within the Earth Science Technology Office (ESTO), that will accommodate four new designated observable (DO) studies as recommended by the latest Earth Science Decadal Survey. Mr. Tupper reported that he just had learned that NASA delivered and integrated detectors for the European Euclid mission, after remediation of sensor problems, and is now working on flight spares.

Regarding JWST progress, Dr. Zurbuchen noted that the science payload completed cryogenic testing in 2017; the science payload integration into the spacecraft is planned for fall 2019. The JWST overrun is being covered by a diversion of some funds for Astrophysics probes and from Headquarters reserve. Launch remains on schedule for March 2021. The only concerns are some remaining technical issues, but a recent independent schedule assessment was positive on this front. WFIRST work continues under a new Program Manager (PM) under an appropriation of $312M. WFIRST is running under the $3.2B cost cap, without Agency reserves, at a 50% confidence level. At the 70% level, the cost cap is $3.9B.

The Mars 2020 rover is on track for a 2020 launch. Three major instruments have been delivered to the Assembly, Testing, Launch and Operations (ATLO) stage. The Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals (SHERLOC) instrument has concluded its risk review after having addressed flight laser power problems. The SHERLOC flight unit will be delivered by the end of June. Priorities for Mars 2020 are mission success, schedule, and cost, in order of descending importance. All other systems are due to be delivered over the next several months. The landing stack is already assembled. Dr. Zurbuchen and the Mars 2020 leadership team meet once a month. With MSR in view, the FY20 President's budget request supports a launch no earlier than 2026, bearing in mind that an ascent module will need to be developed for the Mars surface. Future work for a sample return facility is pending new deliberations in planetary protection, where a new, scientifically informed and updated policy is needed. The Interior Characterization of Europa using Magnetometry (ICEMAG) instrument for the Europa Clipper has been terminated in Phase B, due to cost growth, and has been replaced with a simpler instrument, a fluxgate-only magnetometer. A new science team leader will be appointed, and the study team will retain all ICEMAG co-investigators.

Interdisciplinary science continues to support the three core tenets of the NASA Science Plan. SMD is learning how better to encourage interdisciplinary studies through aggressive pursuit of means to enable cross-cutting research in ROSES (Research Opportunities in Earth and Space Science), and by creating new constructs like the Nexus for Exoplanet System Science (NExSS). Dr. Ozel asked what the framework is for interdivisional grants, Dr. Lori Glaze explained that the Exoplanets Research Program is currently a single call, however, it evaluates all proposals and makes selections cross-divisionally. SMD is looking at an alternative model for the future. The intent is to have one place to go for exoplanets with support from all four divisions. The budget for exoplanets remains the same, and SMD also is trying to be more agile and responsive to community needs.

Mr. Tupper concluded his briefing by commenting that overall, the science program is going very well, and that SMD is grateful for community and Congressional support.

Moon to Mars Plans

Panel 2: Architecture for Science at the Moon and Mars
Dr. Glaze opened the discussion with science results from LRO, indicating that there may be recent tectonic activity on the Moon, and tectonic activity at present. In addition, data have been accumulating on lunar water ice distribution, supporting studies on ISRU for a 2024 lunar lander. The Planetary Science Division (PSD) also is working closely with HEOMD on multidisciplinary science that can address future human exploration, through the Solar System Exploration Research Virtual Institute (SSERVI), which is now establishing its 11th team. Nine teams selected in 2014 will be rolling off, and four teams selected in 2017 will continue. PSD is working with the Korea Pathfinder Lunar Orbiter (KPLO) through a NASA Participating Scientist (PS) program, intended to enhance and augment scientific return from the mission. The PS call received 40 Step-One proposals. In other highlights, the Mars Curiosity rover is increasing understanding of the surface of Mars. A site has been selected for Mars 2020: the Jezero Crater, which includes an ancient river delta that is of interest to both science and human exploration. An agreement was signed last year between the European Space Agency (ESA) and NASA to study a notional MSR architecture. The architecture features two launches, one U.S. and one European, perhaps as early as 2026. A U.S. launch would include a fetch rover to retrieve sample capsules previously collected by Mars 2020 that would then be transported to an Earth-return orbiter provided by ESA. Preparing for human exploration of Mars, NASA carried out a Mars Human Landing Site Study that identified 47 candidate sites. A water mapping effort on Mars is underway. MSR has been working with the Planetary Protection Office (PPO) on standards and on outreach through conferences/workshops and STEM programs and competitions. The International Mars Exploration Working Group (IMEWG) has identified priorities such as ISRU and assessment of the radiation environment. Dr. Zurbuchen has established a task group that will include broad expertise to evaluate where planetary protection should be going.

Mr. Steve Clarke presented via telecon and Webex on efforts to develop the architecture for science at Moon and Mars. SMD and STMD are working together on all aspects of human exploration through an integrated effort that began in summer 2018, the Lunar Discovery and Exploration Program (LDEP). Through LDEP, STMD has been working closely with all the SMD division directors to look for integrated opportunities. One example is in the Deep Space Gateway effort, in which STMD served as the office to work with SMD to review documents, through Dr. Ben Bussey, Senior Scientist from SMD. Dr. Sarah Noble of SMD also provides a third of her time to the integrated effort. The program is working on hiring a Program Scientist. LDEP includes the CLPS, Development and Advancement of Lunar Instrumentation (DALI), LRO mission operations, and developments in communications and data relay. Nine CLPS contracts were announced in November. CLPS is on track to award its first task order within months. The goal is to pursue a contracts cadence of one to two per year. If successful, NASA envisions multiple companies that can deliver instruments to the lunar surface. The program is looking at landers that can take larger masses, to eventually develop larger rovers with science payloads. The first CLPS

mission includes 13 payloads selected from various NASA centers, a mix of science instruments and technology demonstrations, some of which will be ready to fly at the end of 2019. NASA expects to be one of many customers buying rides to the lunar surface.

NASA has released an announcement, with award selections planned in the June timeframe, for a lunar rover launching in 2022 targeting the lunar South Pole. The rover will be a NASA in-house build, but the Agency first wants some ground truth on volatiles. A Request for Information (RFI) has been issued to industry to determine potential commercial sources to assess lunar volatiles, and NASA is carrying out ongoing discussions with potential international partners. LDEP is stitching together a strategic roadmap on how to keep international partners engaged and contributing. NASA had a laser retroreflector assembly (LRA) on the recent Israeli lander, Beresheet; Chandrayaan-2 will carry a similar NASA LRA. NASA's Deep Space Network (DSN) also provides support for these international missions. NASA is talking with Italy, Japan, and other space agencies to support future collaborations. STMD continues to interface with the other SMD division directors. The latest Astrophysics Small Explorer (SMEX) Announcement of Opportunity (AO), included a proposal to use Gateway as a communications and relay asset for the SMEX mission. Mr. Clarke expected other SMD missions to follow suit. LDEP is also working with HPD to improve space weather forecasting, improve models, and determine how to feed data into go/no-go decisions for crews at both Gateway and on the lunar surface. A workshop was held in February 2018 to get a sense of what could be done for science at Gateway, and it had a healthy response from all divisions of science. Also, the National Academies soon will release a study on science that can be performed at the Gateway.

Dr. Ben Bussey provided the science rationale/strategy for lunar exploration, in terms of potential for Decadal Survey science. There are three areas of interest that have been identified as the result of a new analysis of Apollo samples: select and analyze rocks of different lithologies than that of Apollo; determine the distribution and timescale of volcanism on the Moon; and understand the polar distribution and chemical and isotopic compositions of hydrogen-rich volatiles. Three lunar missions supported by the Decadal Survey are: South Pole Aitken Basin Sample Return, Lunar Geophysical Network, and Lunar Polar Volatiles Explorer. These missions aim to understand the history of the Solar System through studying impact craters on the Moon, understand the processes that shape planetary bodies, promote the use of the Moon as a platform for novel and unique measurements, and understand the distribution and quantity of lunar volatiles with respect to lunar ISRU. These missions also aim to achieve Decadal Survey objectives, performing research to science standards while supporting human exploration. Precursor robotics will be used to study lunar impacts, which in turn will drive increased robotic rover capability including mobility and sample return. The plan is to release awards for science instruments annually, including for CLPS and Gateway opportunities.

SMD is developing an exploration science mission plan for the first human return mission and is meeting regularly with HEOMD. Phase one, 2019-2024, is concentrating on how a crew on the lunar surface can enable science. A trained observer on the surface can select samples of the highest scientific value, as demonstrated during the Apollo era. Humans are also superior in their ability to set up intricate experiments on the surface, compared to robots. Human/robotic interaction, including telerobotics from Earth, is also being evaluated; rovers can go beyond where humans can go safely, or find scientifically interesting areas that can't be accessed by humans. It is envisioned that CLPS will be used to perform realistic science achievements, including the first direct measurement of polar volatiles, the first surface magnetic measurement at a lunar swirl, exploration of young volcanic features, and evaluation of far-side radio silence. CubeSats could acquire new scientifically valuable datasets, including global mineral mapping, global elemental maps, and improved volatile mapping. Dr. Hoffman asked about the use of hoppers to reach places unreachable by crews or rovers. Dr. Bussey said that hoppers are definitely in contention, and are considered next-level technology, particularly if one can generate fuel on the surface. Dr. Wadhwa noted that the schedule for sample return (2024) is when the first humans would purportedly

land, not sooner. Dr. Bussey commented that this ultimately would be driven by how fast CLPS prioritizes sample return capability.

Lunch Presentation: *Detecting the Shadow of the Black Hole in M87*
SC Member Dr. Feryal Ozel provided a presentation on the historic event of black hole being imaged for the first time. The image of the black hole in the M87 galaxy, released in April, was produced via an internationally collaborative effort using radio telescopes around the Earth. Dr. Ozel detailed the analyses completed to determine the black hole's shape and mass, emphasizing that the results supported Einstein's theory of general relativity.

Goals of the Meeting
Dr. Wadhwa reviewed the goals of the meeting, i.e. to consider whether SMD is prioritizing the right lunar science, whether any considerations are missing, and whether any mission-critical items are needed for the Agency. Dr. Noble addressed the documentation and activity underlying NASA directions in science at the Moon, including output from a major, decade-old workshop (Science Context for Exploration at the Moon (SCEM)), the Decadal Surveys, National Academies reports, and lunar landing site and Gateway workshops. There also is input from the Lunar Exploration Analysis Group (LEAG) on sample curation.

Science Strategy of the Moon
Dr. Wadhwa invited feedback on the Science Strategy of the Moon presentation. Dr. Hoffman noted that the study of humans in a partial-gravity environment is missing, and could be essential for Mars planning, as long-term effects of space flight and extraterrestrial habitation are unknown. Dr. Noble said that human research occurs outside of SMD, at HEOMD. Dr. Hoffman asked to hear more about this aspect, and Dr. Wadhwa noted that the matter could be taken up during a joint session with the Human Exploration and Operations Committee (HEOC). Mr. Mark Weiser commented that both high-speed computing and DTN are enabling technologies, and while he was not sure they should be part of the science goals, time is critical for communication with humans on the Moon. Dr. Ozel agreed that the SC needs to think about communications infrastructure; it is a two-way street between science and communications. Dr. Avery was not convinced that high-temporal frequency of Earth observations was suitable as a science investigation for the Moon: what do you get from the Moon that you don't get from Gateway or geostationary satellites? Other members agreed that the Moon as a platform for novel and unique measurements for Earth science was questionably supported. Dr. Michael Liemohn commented that the Moon has a unique plasma environment that essentially provides a small natural laboratory for the measurement of solar wind and fundamental plasma physics. Dr. Larson addressed the progress that has been made between Apollo and the present, and that NASA might be more proactive about this story line. Dr. Noble said SMD has been discussing this, and agreed it should be made more explicit. Dr. Tamara Jernigan said she frequently is asked why NASA is going back to the Moon by persons who do not understand the Moon's relevance to Mars; NASA should address this lack of understanding. Dr. Ozel felt that the scientific goals could be better articulated, to better communicate the reason NASA should go to the Moon and Mars; the Strategy should be a better reflection of the reason. Dr. Wadhwa sought to clarify the audience for the Strategy. Dr. Kathryn Flanagan noted that in the past, NASA strategy documents were generated by the community, and that these documents could be better integrated with the Decadal Survey process. With more community input and some nuance, the Strategy could be transformed into a more inspiring document. Dr. Desai warned against the unintended consequence of diverting funding from existing programs. Dr. Flanagan noted that the Decadal Surveys usually endorse new missions, which come with new money. She also recommended developing succinct elevator pitches for the science goals. Dr. Hoffman said a site survey must precede a far-side radio observatory. With regard to polar volatiles, it has been 20 years since Clementine, and NASA has done very little to follow up on confirming its findings. He recommended that a site survey be elevated as a priority for science goals at the Moon. Dr. Noble said the SCEM report prioritizes this goal.

Dr. Wadhwa asked that Committee members look over the three meeting goal questions (appropriate lunar science, missed opportunities, and mission-critical pieces for NASA) and be ready to discuss findings and recommendations the following day.

Public Comments
No public comments were noted.

Diverse Teams and Safe Environments: Report from the Subgroup
Drs. Liemohn, Flanagan and Shepherd reported on their respective delvings into how various communities support safe environments and diverse teams.

Dr. Shepherd investigated diversity and inclusion best practices at the American Meteorological Society (AMS), and the University of Georgia, having had many thoughts about the subject for 20 years. He authored an article in *Forbes* Magazine that addressed the gap between underrepresented minorities and white/Asian populations in STEM. The University of Georgia's best practices include a Certificate in Diversity and Inclusion (staff training). Dr. Shepherd felt that training constituted half the battle. The University also hosts the Peach State LSAMP (Louis Stokes Alliances for Minority Participation) program, a long-term National Science Foundation (NSF)-funded effort that targets other universities as well. It is a robust model that could be used as a model at NASA. The University also operates under a five-year diversity plan, raising the questions of whether NASA has a strategic plan for diversity, and should it. AMS has a diversity statement on file with regard to women and minorities, and offers the Charles Anderson Award for Mentorship and the Joanne Simpson Mentorship Award, an AMS Minority Scholarship, and the Color of Weather and CORIOLIS receptions. He reported that Dr. Avery explored a proposal to elevate diversity and inclusion to a commission level within the AMS.

Dr. Liemohn reported that the American Geophysical Union (AGU) recently created a strategic plan with five main goals, which was adopted by the AGU Council in December 2018. The AGU also developed an Ethics Implementation Plan, which requires a conduct disclosure statement for honorees and leaders. Any violations are reported to ethics@agu.org. AGU has also Instituted SafeAGU training for staff and leaders, and has created an AGU Ethics and Equity Center. As an aside, Dr. Liemohn said that his home institution, the University of Michigan, has expanded its grant from the NSF Advance program with internal funding.

Dr. Flanagan reported on best practices for diversity at the Space Telescope Science Institute (STScI). There is both an inward effort, and an external component of diversity at the Institute. Dr. Flanagan said that STScI has worked to uncover unconscious bias in both men and women, which definitely enters hiring and promotion practices, and in the reception of resumes and letters of recommendations. The Institute uses practices in recruitment and hiring: educating hiring managers; establishing job-related criteria at the outset for successful applicants; wording job descriptions broadly; expanding recruitment to generate diverse applicant pools; applying pre-established criteria to applicants; managing the interview process for consistency; and validating the short list to see if it is reflective of the candidate pool. If the short list is sufficiently diverse, the effort can be stopped at that step. The Institute also has closely studied peer review panel guidelines, considering what constitutes a diverse review panel in terms of gender, geography, seniority, institution type, and race/ethnicity. The Institute provides presentations on unconscious bias, and conducted its first experiment in a "dual anonymous" Hubble Space Telescope proposal review, wherein proposers did not know the reviewers and vice versa. This experiment seemed to make disparities disappear. The dual anonymous review approach might be something NASA could apply to ROSES calls.

As for long term goals: should NASA/SMD try to stem the leaky STEM pipeline? Dr. Ozel commented that the Astrophysics Advisory Committee had featured a briefing by Drs. Michael New and Joan

Centrella addressing the subject of diversity and inclusion, which she would send to the SC. One other issue of relevance involved a study of mission Principal Investigator (PIs), with striking results. She highly recommended attending the "PI 101" workshops at NASA, which have recently begun. Dr. Ozel had the sense that it would be easier to anonymize a short four-page proposal, but that in a major proposal, one would have to go to greater lengths to anonymize information. Dr. Noble said Dr. New was very interested in this approach and would like to launch test cases for ROSES. Dr. Wadhwa thought it might be useful for NASA to consider a five-year strategic plan for diversity, per Dr. Shepherd's presentation on AMS. Dr. Avery commented that any effort should be focused on diversity, equity and inclusion, to avoid the numbers game. In most cases, this effort gets buried in a human resources (HR) department and is never elevated to the fuller perspective of equity and inclusion. This tripartite awareness should be embedded in and raised to the awareness of the very top of an organization, and the philosophy should pervade the work environment. She noted that the University Corporation for Atmospheric Research (UCAR) is doing this, to great effect. Dr. Flanagan agreed, noting that at STScI, the head of the HR department sits at the highest level of executive meetings. Dr. Larson noted that in the corporate realm, HR does sit in the C-suite, and addresses the issue in the context of human capital. Mr. Weiser thought that a formal certificate and in-depth training were powerful ideas, resulting in attracting hirees with a similar mindset. Dr. Jernigan commented that Yale University's Dr. Meg Urry had reported backlash to training. Drs. Shepherd and Flanagan reported the same results, in their experience.

New Technology Entrepreneurial Partnerships

Mr. Michael Seablom reported on an autonomy workshop at Carnegie Mellon in 2018 that identified needs for future missions. NASA is still gleaning results, with a final report due for completion in July. A panel review on procurement methods found that NASA is not on the bleeding edge of autonomy; NASA concluded that methods must be updated and augmented. NASA will host an Innovation Oktoberfest this fall and invite industry to participate. There will be panel discussions with space technology venture capitalists, idea pitches by start-ups, and ranking of ideas. The purpose is to provide SMD project managers experience in working with venture capitalists and nontraditional innovators, to help embolden science visions. NASA is interested in revolutionizing the program with regard to the procurement of hardware and services, and providing exposure for project managers, in order to improve business acumen. Mr. Seablom thanked Mr. Weiser for his advice in this matter. Mr. Weiser noted that this will help NASA think about higher risk/higher impact; there is much autonomous technology out there for NASA to consider. The major challenge will be to identify where NASA will want to start.

Division Advisory Committee (DAC) Chair Report – Earth Science

Dr. Shepherd, Chair of the Earth Science Advisory Committee (ESAC) provided the committee report; first noting a refresher on the major elements of ESD's strategic objective: to advance knowledge of Earth as a system, to meet the challenges of environmental change, and to improve life on the planet. ESD's Applied Sciences Program (ASP) is shifting the paradigm as NASA continues to work closely with the organizations it serves to better deliver social benefits. Science highlights include the receipt of valuable data from the GEDI (Global Ecosystem Dynamics Investigation) lidar instrument, which monitors the forest canopy profile. ECOSTRESS (ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station), which leverages the International Space Station (ISS) for science, is providing data on urban heat islands, showing that these can be up to 8°F degrees hotter than the natural landscape. ECOSTRESS also is able to measure evapotranspiration, aiding farmers in making decisions to irrigate. In its first three weeks over Antarctica, ICESat-2 is showing how the polar regions are feeling the brunt of climate warming. Rising temperatures at the poles are affecting the Earth's larger weather patterns. Recently, the loss of 20,000 Emperor penguins was attributed to ice shelf destruction in Antarctica. ICESat-2 also weighed the A68A iceberg from space, the result of a major calving from the ice shelf. A68A measured in at five times the volume of Lake Erie. ICESat-2 has other applications, such as imaging built structures vs. vegetation on the California coast, and providing bathymetry data on the Pacific Ocean's Bikini atoll.

ESD is moving forward on finishing with its last Decadal Survey, as it rolls out the new one. Dr. Avery thanked Dr. Shepherd for his proactive article on the 5G problem, in *Forbes* magazine, and asked whether ESAC had reviewed the issue of 5G networks operating in the context of weather satellites. Dr. Shepherd noted that the 5G network operates in the frequency associated with water and cloud signals, raising concerns about what this interference means for forecasting and models. The discussion will be on a future ESAC meeting agenda. Dr. Avery commented that NASA and NOAA have come out strongly to the Federal Communications Commission (FCC), as the issue has just recently gotten into the news. The FCC seems to have been ignoring the issue, to date. Dr. Shepherd felt that this was a case where major science organizations such as AMS and AGU must chime in and be vocal.

Day 1 Wrap-Up

Dr. Zurbuchen returned briefly to present a few final slides from the morning session. He reported that a new Planetary Protection Independent Review Board has been set up that will deal with forward and backward contamination associated with space exploration. In response to NAC and National Academies of Sciences, Engineering and Medicine (NASEM) advice, the board will assess planetary protection guidelines in the context of the current exploration landscape, and will review and recommend updates to biological contamination guidelines developed by the Committee on Space Research (COSPAR). This will provide direction for future planetary missions, including MSR. The review board will be chaired by Dr. Alan Stern. NASA also has proposed establishment of a Science of the Moon Subcommittee; Administrator James Bridenstine had announced the intent in August 2018. The Subcommittee will support the advisory needs of NASA SMD, and other directorates as needed, for exploring science opportunities at the Moon. The Chair will be a SC member, and the Subcommittee will consist of 10-20 lunar science experts from industry, academia, and government, as well as independent researchers. An extensive and diverse candidate pool is being reviewed at present.

Dr. Wadhwa asked Dr. Zurbuchen about the intended audience for the Science Strategy at the Moon document. Dr. Zurbuchen said that the strategy communicates priorities to stakeholders, and also functions as a decision-making tool. He welcomed feedback on improving and clarifying the document. Proposers are the target, essentially, as the document seeks to elucidate NASA's research priorities. Dr. Zurbuchen felt the strategy should enable the best ideas to rise to the top. He noted that there are multiple stakeholders at OMB who also read this document.

May 22, 2019

Ms. Denning re-opened the meeting. Dr. Wadhwa introduced the day's agenda, noting that this is the last meeting for Drs. Flanagan, Jernigan, Shepherd, and Desai. She thanked them for their tenure.

NASA Science Plan

The Committee discussed their response to the NASA Science Plan, 2019-2024. Dr. Hoffman said he found it difficult to find anything to criticize; he felt the science program was working well, and was on a good track. Dr. Larson thought the Plan lacked an overarching contextual story, because the introductory material seemed disconnected from the rest of the report, which is generally well written. Dr. Avery felt that many paragraphs within the main body of the Plan were worded more inspirationally than the introduction. Dr. Liemohn remarked that the three themes in the introduction, and particularly the photos, seemed more focused on Earth. He suggested more general language: "advancing the frontiers for humanity" or "unlocking the mysteries of our planet." Dr. Avery agreed that the Plan should emphasize discovery (including Earth science discoveries) aspects, with the understanding that Earth science mission prioritization may include answering questions essential to Earth science applications. Dr. Wadhwa noted that in the context of the focus on diversity in science in this document, the photos in the document are male-dominated. Dr. Hoffman said the Plan lacked a discussion of the science of human beings in space, and the science of the exploration program.

Dr. Zurbuchen suggested that the SC recommend specific inclusion of human exploration science, but that he did not know how to make it actionable. The Plan is used to organize SMD's work, and to communicate with the science community at large, as well as Congress. Dr. Jernigan thought that the life science aspect would not inform SMD priorities, and asked if there was a corresponding document on life sciences in HEOMD. She felt that mentioning the fact that life sciences are not included in SMD might make an incisive point. Dr. Avery pointed out the lack of a technology development section that informs science. Dr. Hoffman liked Dr. Jernigan's suggestion of just mentioning that life sciences resides in exploration.

The Committee continued review of the Plan. Dr. Avery worried that some Earth system stakeholders may not see themselves in NASEM discipline-specific guidance; ocean scientists, for instance. Dr. Larson said she thought the document reflected the fact that a SMD cross-disciplinary philosophy was actually in place, despite Decadal Survey stovepiping. Dr. Ozel felt that the strategy statements were not ambitious enough in terms of astrophysics, and that these seemed to expressly defend Decadal Survey (DS) lanes. Dr. Zurbuchen said that defense was not what SMD had in mind. The purpose of the document is to reflect the priorities in place in order to make the hard decisions such as taking instruments off Flagships, and allow implementation of a balanced program. Is there a balanced program in Astrophysics? The community should tell SMD, not the other way around. He felt that ESD was the strongest in the sense of a balanced program. Dr. Ozel said she was not getting the sense of the wonder of the universe; the document seemed the least developed in terms of Astrophysics, and not ambitious enough in words. Mr. Weiser asked: how do you choose to balance the program? In terms of social impact, science, dollars? Dr. Ozel commented that the Decadal Survey typically looks at Flagships vs. probes, large missions vs. small. Dr. Flanagan said that the Decadal Survey prioritizes strategies; it doesn't discuss the Explorers program, make decisions about operating missions (i.e. turning them on or off), or address the technology workforce or hardware production. The community must understand the limitations of the Decadal Survey. Dr. Zurbuchen noted that NASA has given NASEM more room in the Decadal Survey to think about trade space, because it is such a difficult problem; they now can provide recommendations on developing missions. He added that the communities must come together behind their Flagship missions, or else they should not be done.

Dr. Zurbuchen recapped the Vision, Mission, Values, and Focus Areas approach to the NASA Science Plan to facilitate further discussion. Ms. Ellen Gertsen commented that this newest Plan is a much shorter document that attempts to think about communities in a different way. Dr. Larson felt that the introduction describes the "state of the state," and should be fleshed out more. Dr. Wadhwa appreciated the conciseness of the Plan, but felt it was missing the connection back to the technology directorate of the Agency, and she also saw some gaps with the exploration side connecting with the science side in Mr. Clarke's briefing. Dr. Ozel said it would be good to state that a culture of innovation is desirable, and that risk is involved. Dr. Liemohn suggested that a statement of diversity, inclusion and equity could also be included in Strategy 2.2. Dr. Ozel felt that the wonder of exploration and of astrophysical discovery was lacking: the "why" of discovery. Dr. Zurbuchen welcomed edits, but noted that a balanced program is not an entitlement exercise. Right now, NASA is training the next generation with PI-led missions, not only because it's an important human endeavor, but because these new PIs will lead future Flagships. Mr. Weiser recommended highlighting NASA's culture of innovation, while celebrating scientific victories around these guiding principles of measuring performance.

Dr. Liemohn liked how the Plan aimed for the 2024 future state, and that further wording to this effect would be great in the document. Dr. Zurbuchen said he had seen some discouragement and loss of hope in NASA and the science community, and wanted them to see the Plan as a genuine attempt to re-engage scientists. Dr. Flanagan emphasized the new focus on cross-disciplinary science, innovation, and the possibility of "watering a new garden." Implementation is what happens on the ground, through NASA

centers, and making innovation happen will require a culture change. Even for a Class D mission, the entire first year is writing documents. Is there a way to have a "management- lite" approach? Dr. Zurbuchen agreed. It is not necessary to have 51 documents for a key decision point (KDP) milestone; that is ten times too many. How can it take a year to fail a KDP? NASA clearly needs faster iterations. Dr. Ozel commented, in terms of a disenfranchised community, that if people see more risky proposals funded, and more diversity in proposals by 2024, they will take NASA's Science Plan to heart. Dr. Liemohn said that people get disgruntled when their proposals get turned down; they need to see an explicit "striving for fairness" statement. Dr. Ozel noted that the Astrophysics Theory Program still demonstrates significant gender bias in proposal acceptance. Dr. Desai said that the best thing NASA can do is to be transparent to the proposer; he had never been upset at losing a proposal, only at not getting a fair shot. It is important to be honest when you accept and reject; NASA is getting there, but is not there yet.

The SC made writing assignments on a number of findings such as the need for a more visionary and ambitious introduction; more focus on discovery in Earth science; the link between life sciences and exploration; teamwork, equity, and inclusion; and interconnectivity across directorates; among other aspects.

Science Strategy at the Moon Discussion

Dr. Wadhwa reiterated the main findings on the draft of Science Strategy at the Moon; i.e. add an overarching rationale, and the "why" of the Plan. Dr. Larson suggested adding the narrative of why NASA should go to the Moon, given the advances in science and technology, and also why the Moon should precede Mars. Dr. Desai was concerned that NASA's science budget would be harmed by diversion of funds to Moon exploration. He said he would rather piggyback science on Moon exploration, rather than soundly endorse it. Dr. Wadhwa felt that the SC should view the Moon as an opportunity, and focus its efforts on defining the science rationale, regardless of the programmatics. Dr. Flanagan commented that we already know exploration will have an impact on SMD; should the SC simply state it? Dr. Wadhwa recommended sticking to the question and attempting to prioritize the science NASA does have, as this is a strategy document. The SC discussed some minor edits and made writing assignments.

DAC Chair Reports

APAC

The Chair of the Astrophysics Advisory Committee (APAC), Dr. Ozel, reported on the committee's latest deliberations and science highlights. The Transiting Exoplanet Survey Satellite (TESS) discovered its first Earth-sized planet, with a radius of about 90% that of Earth, and an 8-day orbital period. There are new Hubble data on the expansion rate of universe, based on measurements of supernova cosmology vs. local distance scale. The discrepancy continues to grow; the current discrepancy is at 5 sigma at present, based on direct measurement vs. extrapolation from cosmic microwave background (CMB). A new signal for neutron star collision has been discovered, via Chandra Deep Field South observations, based on archival data of x-ray bursts. The Laser Interferometer Gravitational Wave Observatory (LIGO) was not active at the time of the observations (2015); had it been, it would likely have detected an event. Recent developments stemming from the new Astro 2020 Decadal Survey include the selection of the Imaging X-ray Polarimetry Explorer (IXPE) and Galactic/Extragalactic ULDB Spectroscopic Terahertz Observatory (GUSTO).

The Astrophysics Division had been in a critical stage of looking at mission portfolio at the time of the government shutdown in early 2019, thus APAC will hear the results of the Senior Review in a telecon later in June. Congressional language has directed that SOFIA undergo an external independent review. The Senior Review will include Hubble, Chandra, XMM (X-ray Multi-Mirror Mission)-Newton and NuStar (Nuclear Spectroscopic Telescope Array), among others. Decadal Survey planning is also under way, with four large mission probe concept studies, whose final reports are to be submitted to NASA this

summer: these are the Habitable Exoplanet Observatory (HabEx), Large UV Optical Infrared Surveyor (LUVOIR), the Origins Space Telescope, and the Lynx X-ray Surveyor. The studies then will be submitted to the Decadal Survey, the most comprehensive ever provided. There also are nine probe concepts under study. Science white papers have been submitted and programmatic papers will follow.

APAC has been discussing recent failures in the balloon program, and is hoping to see a reversal in the trend, as a potential cause has been identified. Discussions continue on increasing diversity in PI-led missions, and whether there are barriers to cross-divisional science proposals. The APAC is conducting an informal community survey to address the latter issue. Dr. Verbiscer asked if the independent SOFIA reviews would feed into APAC. Dr. Ozel said that as the reviews are not part of the Senior Review, APAC will hear the results separately. Dr. Paul Hertz, Director of APD, reported that he had received one of the two SOFIA reports, and had begun providing direction to SOFIA to improve its science program over the next three years.

HPAC

Dr. Liemohn, Chair of the Heliophysics Advisory Committee (HPAC), noted that the HPAC still needs a new charter, due to the interruption of the government shutdown. He presented some science nuggets, the first being the Parker Solar Probe's (PSP's) second periapse pass, which yielded results that were unprecedentedly good. The PSP is observing radial component of magnetic fields, seeing them flipping many times per day. GOLD, a mission of opportunity on a commercial satellite, has released first light images that are fantastic.

HPAC had its last meeting in December 2018, the day before shutdown. At that last meeting, HPAC concluded that HPD is doing very well under the new leadership of Dr. Nicky Fox. HPAC considered a report from the Science and Technology Definition Team (STDT) on the Geospace Dynamics Constellation (GDC) Flagship, which is a fleet of Earth-observing satellites. Due to Federal Advisory Committee Act (FACA) rules, the STDT was forbidden from looking at instruments, to avoid conflict of interest (COI). HPD, therefore, is going to need instrumentation feasibility studies on GDC. Dr. New enumerated some ways to deal with future mission concept studies that might include instrument discussions (through grants or contracts). The GDC STDT final report is due in July. GDC will be going to the upper atmosphere, and should be able to take advantage of existing ground-based assets to round out its measurements. HPAC also considered whether NASA should be required to extend the length of its prime missions to 5 years for Flagships and 3 years for Explorers. HPAC disagreed with this move because it could be a cost driver. HPAC did agree with allowing changes to Level 1 operating requirements at each Senior Review. The Whole Heliosphere Interactions campaign is starting up, with the advent of PSP operations, and there has been discussion of engagement with ESA. Because ESA does not have an exact one-to-one match with Heliophysics at NASA, HPAC is asking HPD to work more effectively across the boundaries to make the collaboration happen.

Dr. New provided some background on origin of the COI issue in STDTs, explaining that NASA's Office of the General Counsel (OGC) had directed that both STDTs and Senior Reviews be made FACA-compliant, because these are considered potentially advisory in nature. Dr. Avery asked if this meant that future missions would be unable to benefit from discussions with other agencies. Dr. New said that one of the workarounds is to hire contractors to produce a report, to produce the necessary input. Dr. Fox noted that the GDC STDT did have input from ESA, couched as a simple lessons-learned briefing; she agreed that the FACA designation is constrictive. Dr. Avery said that such restrictions limit the ability to really understand what is going on in the systems under study, such as space weather, which makes it hard to do strategic planning. Dr. New noted NASA will need to adapt to the new legal environment, and will have to learn to obtain what is needed; the communities can still talk to one another. Dr. Desai said he did not see a problem with not talking about instruments.

The SC expressed concern with this last development and its potential for hampering ideas to feed into the Decadal Survey, and discussed a potential finding on the subject.

PAC

Dr. Verbiscer, Chair of the Planetary Advisory Committee (PAC), noted that the committee had been hampered from meeting by the government shutdown, during which time the PAC charter had expired. Dr. Lori Glaze, PSD Director, said there had been movement on the charter. Dr. Verbiscer reported hearing a lot of frustration from members, who wanted very much to meet in person. The ICEMAG cancellation was a big hit to the planetary community, and there has been no vehicle to express feedback. The next face-to-face meeting for PAC is scheduled for June 12-13. The PAC also is due to receive a report from the Planetary Mission Senior Review subcommittee (6 missions, 5 Mars missions, plus LRO) on June 28. Science highlights in PSD include the exploration of a cold classical Kuiper Belt Object (KBO) by New Horizons; data indicating water on the Moon from the Lunar Atmosphere and Dust Environment Explorer (LADEE) and LRO; and new observations on the frequency of cratering on small bodies in the outer Solar System. From observations of Pluto and Charon during the New Horizons flyby, there is a distinct lack of cratering on these bodies. Similar distributions are seen on the Jovian moons, Europa and Ganymede. A New Horizons paper on the KBO Ultima Thule (MU69) can be found in the current issue of *Science* (May 17). The shape of Ultima Thule is unusual; it is a contact binary object. Its shape had been confirmed from prior occultation measurements, but direct imagery indicates that it is surprisingly flat. The object's conformation is thought to be result of a gentle collision between two independently formed bodies. It is likely to have water ice on surface, maybe methanol ice. The object is very dark and red. Dr. Desai asked what would be next for the New Horizons mission. Dr. Verbiscer said it will be considered in the next senior review; the mission is considering another target as it moves out of the densest portion of the Kuiper Belt. There is broad, cross-divisional science that can be done in an extended mission.

Discussion, Findings and Recommendations

The Committee discussed and refined their recommendation and findings. These included one recommendation on a multi-tiered strategy to facilitate diverse teams and safe environments at NASA and 12 findings – four on the Science Strategy at the Moon, seven on the NASA Science Plan, and one on STDTs.

Outbrief to SMD AA

Dr. Wadhwa summarized the Committee's recommendation and findings to Dr. Zurbuchen, who expressed his appreciation on the constructive nature of the products, and said he was prepared to take action on several. Dr. Wadhwa thanked the members of the SC who were rotating off, as did Dr. Zurbuchen. Dr. Zurbuchen added that the SC should feel empowered to use its voice moving forward as to any points of view that are missing and where the opportunities are to do better. Dr. Wadhwa adjourned the meeting at 2:53 pm.

Appendix A
Attendees

NAC Science Committee Members
Meenakshi Wadhwa, Arizona State University, ***Chair, Science Committee***
Susan Avery, Woods Hole Oceanographic Institute
Vinton Cerf, Google *(via telecon/WebEx)*
Michelle Larson, Adler Planetarium
Michael Liemohn, University of Michigan, Chair, Heliophysics Advisory Committee
Mihir Desai, Southwest Research Institute
Kathryn Flanagan, Space Telescope Science Institute
Jeffrey Hoffman, Massachusetts Institute of Technology
Tamara Jernigan, Lawrence Livermore National Laboratory
Feryal Ozel, University of Arizona, Chair, Astrophysics Advisory Committee
J. Marshall Shepherd, University of Georgia, Chair, Earth Science Advisory Committee *(via telecon/WebEx)*
Anne Verbiscer, University of Virginia, Chair, Planetary Science Advisory Committee
Marc Weiser, RPM Ventures
Elaine Denning, NASA Headquarters, ***Executive Secretary, Science Committee***

NASA Attendees
Gabriel Adler, NASA OLIA
Ralph Beaty, NASA HQ
Veronica Bindi, NASA
Stacy Brooks, NASA STMD
Sandra Cauffman, NASA HQ
David Chambers, NASA HQ
Daniel Evans, NASA HQ
Jamie Favors, NASA HQ
Nicky Fox, NASA HQ
Ellen Gertsen, NASA HQ
Lori Glaze, NASA HQ
Mike Green, NASA HQ
Therese Griebel, NASA HQ
Josh Handal, NASA HQ
Kenneth Hansen, NASA HQ
Hashima Hasan, NASA HQ
Paul Hertz, NASA HQ
Gib Kirkham, NASA OIIR
Veronica Lang, NASA HQ
Connor Lindsay, NASA HQ
Peg Luce, NASA HQ
Michael New, NASA HQ
Sarah Noble, NASA HQ
Ursula Rick, NASA HQ
Michael Seablom, NASA HQ

Maddy Sisk, NASA HQ
Gerald Smith, NASA HQ
Florence Tan, NASA HQ
Lucia Tsaoussi, NASA HQ
Craig Tupper, NASA HQ
Dan Woods, NASA HQ
Thomas Zurbuchen, SMD AA, NASA HQ

Non-NASA Attendees
Angela Phillips-Diaz, UCSD
Grace Hu, OMB
Ashlee Wilkins, House Science Committee
Ana Wilson, Electrosoft, Inc.
Joan Zimmermann, Zantech IT, Inc.

Telecon/WebEx attendees
Gale Allen, American Society of Gravitational and Space Research
Louis Barbier, NASA HQ
Meghan Bartels, Space.com
DaMara Belson, NASA
Christine McManhon Bognar, OIIR
Theresa Brandt, NASA
Andrew Buckner, UNRA
David Bussey, NASA
Victoria Carter-Cortez, NASA
Stephen Clark, Space Flight Now
Lee Curtis, AURA
Laura Delgado-Lopez, NASA
Franco DeStefanis, ThalesAlenia Space
Marcia Dunn, Associated Press
Kelly Fast, NASA HQ
Christopher Flaherty, NASA
Jeff Foust, Space News
Laura Gatti, ThalesAlenia Space
Helen Grant, NASA HQ
Max Grasso, Avascent
John Gruener, NASA JSC
Allison Hannigan, Xplore Inc.
Brian Harvey, BAN Associates
Kimberly Hurst, NASA
Doug Ispell, NASA JPL
John Karcz, OMB
Jennifer Kearns, NASA HQ SMD
Michael Kelley, NASA
Phoebe Kinzelman, National Academy of Sciences
David Kramer, Physics Today

Miriam Kramer, Axios
Pete Kuhns
Rob Landis, NASA
Lily Larsen, Ball Aerospace
Samuel Lawrence, JSC
Sarah Lewin, Space.com
Aaron Lewis, Arianespace
James Lochner, USRA
Tatia Long, IDA/STPI
Kamala Lyon, University of CA
Dillon MacInnis, SpaceX
Tariq Malik, Space.com
Alex McDonald, NASA
Pamela Millar, NASA
Amanda Miller, Journalist
William Miller, NSF
Dedra Needham, NASA Marshall
Charles Norton, NASA HQ
Natasha Pinol, NASA
Nathan Price, NSS
Arik Posner, NASA HQ
Cheryl Reed, APL
Jeff Rich, Xplore
Maria Rodriguez, NASA
John Rummel, SETI
Tara Ruttley, NASA
Martin Ruzek, USRA
Ryan Schaefer, NASA
Adam Schilffarth, Explore
David Smith, NAS
Marcia Smith, Space Policy Online.com
Bill Stabenow, NASA
Julie Stopar, LPI
Thomas Sutliff, NASA
Will Thomas, AIP
Dan Vergano, Buzzfeed News
Ekaterina Verner, NASA
Monica Vidaurri, NASA
Paul Voosen, AAAS
Ryan Whitley, National Space Council
Alexandria Witze, Nature Magazine

Appendix B
NAC Science Committee Membership

Dr. Meenakshi Wadhwa (Chair)
Arizona State University

Dr. Susan K. Avery
Woods Hole Oceanographic Institution

Dr. Vinton Cerf
Google, Inc.

Dr. Mihir Desai
Southwest Research Institute

Dr. Kathryn Flanagan
Space Telescope Science Institute

Dr. Jeffrey Hoffman
Massachusetts Institute of Technology

Dr. Tamara E. Jernigan
Lawrence Livermore National Laboratory

Dr. Michelle Larson
Adler Planetarium

Dr. Michael Liemohn
University of Michigan

Dr. Feryal Ozel
University of Arizona

Dr. Pat Patterson
Space Dynamics Laboratory

Dr. J. Marshall Shepherd
University of Georgia

Dr. Anne Verbiscer
University of Virginia

Mr. Marc Weiser
RPM Ventures

Ms. Elaine Denning (Executive Secretary)
NASA Headquarters

Appendix C

Presentations

1. NASA Science Overview; *Thomas Zurbuchen, Craig Tupper*
2. Forward to the Moon: NASA's Strategic Plan for Lunar Exploration; *Mark Sirangelo, William Gerstenmaier, Therese Griebel, Thomas Zurbuchen*
3. Moon to Mars; *Lori Glaze*
4. Lunar Discovery and Exploration Program; *Steve Clarke, Ben Bussey*
5. *"Detecting the Shadow of the Black Hole in M87;" Feryal Ozel*
6. Diverse Teams and Safe Environments Follow-on Discussion: Report from the Subgroup; *J. Marshall Shepherd, Michael Liemohn, Kathryn Flanagan*
7. Earth Science Advisory Committee Report; *J. Marshall Shepherd*
8. NASA Science Plan 2019-2024: A Vision for Scientific Excellence; *Thomas Zurbuchen, Ellen Gertsen*
9. Astrophysics Advisory Committee Report; *Feryal Ozel*
10. Heliophysics Advisory Committee Report; *Michael Liemohn*
11. Planetary Advisory Committee Report; *Anne Verbiscer*

Appendix D
Agenda

Dial-In (audio) & WebEx (view presentations online) information is located on page 3.

NASA Advisory Council
Science Committee

May 21-22, 2019

NASA Headquarters
Room 3H42

Agenda
(Eastern Time)

Tuesday, May 21

9:30 – 9:40	Opening Remarks / Introduction of Members	Ms. Elaine Denning Dr. Meenakshi Wadhwa
9:40 – 10:00	NASA Science Overview	Dr. Thomas Zurbuchen
10:00 – 10:45	Moon to Mars Plans	
	Panel 1: Forward to the Moon	Mr. Mark Sirangelo Mr. William Gerstenmaier Ms. Therese Griebel Dr. Thomas Zurbuchen
10:45 – 11:45	NASA Science Overview (continued) FY20 Request	Dr. Thomas Zurbuchen Mr. Craig Tupper
11:45 – 12:30	Moon to Mars Plans (continued)	
	Panel 2: Architecture for Science at the Moon and Mars	Mr. Steve Clarke *(via telecon)* Dr. Ben Bussey *(via telecon)* Dr. Lori Glaze
12:30 – 1:30	*Lunch* – **Member Research Presentation** "Detecting the Shadow of the Black Hole in M87"	Dr. Feryal Ozel
1:30 – 1:35	Goals of the Meeting	Dr. Meenakshi Wadhwa
1:35 – 3:00	Science Strategy at the Moon	Dr. Meenakshi Wadhwa Dr. Sarah Noble All
3:00 – 3:10	*Break*	
3:10 – 3:15	Public Comments	

Dial-In (audio) & WebEx (view presentations online) information is located on page 3.

3:15 – 4:00	Continuing High Priorities Follow-Ups	
	Diverse Teams and Safe Environments	Dr. Michael Liemohn Dr. Kathryn Flanagan Dr. J. Marshall Shepherd
	New Technology Entrepreneurial Partnerships	Mr. Michael Seablom
4:00 – 4:15	Division Advisory Committee (DAC) Chair Reports Earth Science Advisory Committee	Dr. J. Marshall Shepherd
4:15 – 4:30	Day 1 Wrap-Up	All
4:30	*Adjourn for Day*	

Wednesday, May 22

8:30 – 8:35	Re-Open Meeting	Ms. Elaine Denning Dr. Meenakshi Wadhwa
8:35 – 10:00	NASA Science Plan	Dr. Thomas Zurbuchen Ms. Ellen Gertsen
10:00 – 10:15	*Break*	
10:15 – 11:45	Science Strategy at the Moon	Dr. Meenakshi Wadhwa All
11:45 – 12:30	DAC Chair Reports Astrophysics Advisory Committee Heliophysics Advisory Committee Planetary Science Advisory Committee	 Dr. Feryal Ozel Dr. Michael Liemohn Dr. Anne Verbiscer
12:30 – 1:15	*Lunch*	
1:15 – 2:30	Discussion, Findings and Recommendations	All
2:30 – 3:00	Outbrief for SMD AA	Dr. Meenakshi Wadhwa Dr. Thomas Zurbuchen
3:00	*Adjourn*	

Dial-In (audio) & WebEx (view presentations online) information is located on page 3.

Dial-In and WebEx Information

For entire meeting May 21-22, 2019

Dial-In (audio): Dial the USA toll free number 1-888-469-1762 or toll number 1-212-287-1653 and then enter the numeric participant passcode: 8281293. You must use a touch-tone phone to participate in this meeting.

WebEx (view presentations online): The web link is https://nasaenterprise.webex.com, the meeting number is 906 407 923, and the password is SC@May2019 (case sensitive).

** All times are Eastern Time **