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MEETING REPORT

M Wadhwa Feb 25, 2019

Meenakshi Wadhwa, Chair

Elaine Denning March 6, 2019

Elaine Denning, Executive Secretary

[Minutes not completed within 90 days of meeting due to Federal government shutdown 12/22/18-1/25/19]

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November 1, 2018

Opening Remarks

Ms. Elaine Denning, Executive Secretary for the NASA Advisory Council (NAC) Science Committee (SC), opened the meeting with administrative remarks concerning the guidelines and rules established by the Federal Advisory Committee Act (FACA), which govern all FACA committees. She introduced the Interim Chair of the SC, Dr. Meenakshi Wadhwa. Dr. Wadhwa formally opened the meeting and led introductions around the table.

NASA Science Overview

Science Mission Directorate (SMD) Associate Administrator (AA) Dr. Thomas Zurbuchen presented an overview of the directorate. He began the briefing by thanking two mission teams for their efforts and accomplishments: Kepler and Dawn. The Kepler mission is shutting down after 9 years of operation, having exceeded expectations and transformed scientific knowledge; because of the Kepler mission, it is now known that terrestrial, rocky worlds are abundant. Some tools needed to further study these worlds have yet to be invented. Missions in development such as the James Webb Space Telescope (JWST) and the Wide Field Infrared Survey Telescope (WFIRST) will bring astrophysical research forward and build on the strong legacy of Kepler. In addition to enabling amazing research and science, Kepler also has changed the way data are analyzed and distributed, using novel approaches from which others can learn. Regarding the second team, as of midnight the Dawn mission has officially ended, also leaving behind a tremendous legacy. The Dawn mission team took new technologies and put them into a Discovery mission, a Principal Investigator (PI)-led mission that brought the entire community forward. Dawn yielded much information about the asteroid Ceres, whose surface features returned important data about its composition and evolution, and the physical and chemical phenomena that shaped the early Solar System. Of recent note, the Hubble Space Telescope (HST) and the Chandra telescope both went into safe mode for brief periods. Neither event was significant and both missions are back in science mode. Dr. Zurbuchen noted that Chandra is in the 16th year of its planned five-year mission.

SMD highlights are many. The Parker Solar Probe (PSP), one of NASA's fastest missions, has broken all sorts of records for speed of launch to operational status. The mission team is looking forward to the spacecraft's first perihelion pass on November 6, as well as to the first science briefing to Dr. Parker. The mission is expected to be paradigm-changing, as it passes by the Sun at a distance as close as 9 solar radii (Rs). The Transiting Exoplanet Survey Satellite (TESS) will be following the Kepler mission as the next-generation exoplanet hunter, orbiting in resonance with the Moon. NASA already has announced a number of exoplanet candidates, which will soon be followed by a slew of activities. BepiColombo, a venture shared by the Japanese Space Agency (JAXA) and the European Space Agency (ESA), launched successfully in October. It is a two-spacecraft mission on a seven-year journey to Mercury, and carries a NASA instrument called Strofio. NASA is highly interested in the performance of the Ariane V rocket that launched BepiColombo, because an Ariane V will carry JWST in 2021. The October launch was flawless. Solar Orbiter (SO) is an ESA-led mission that will be launched by NASA as early as 2020. Initial work on the spacecraft was done in the UK, and it now has been shipped to Germany for integration. The confluence of PSP and SO will function as an observatory that will serve as an unprecedented platform for new discoveries, particularly in the inner heliosphere. The Earth science mission Ice, Cloud and land Elevation Satellite-2 (ICESat-2) launched successfully in September 2018 on a Delta II rocket. ICESat-2 is studying the reflected light of the Earth's cryosphere. The ice cover is being measured at a two-orders-of-magnitude improvement (an improvement of resolution that is equivalent to going from football-field to yard scale). Initial data from the instrument is excellent. Dr. Zurbuchen pointed out that ICESat-2 went through a difficult development phase. The laser instrument had run into challenges and the mission had to be re-baselined. It is rare to have a mission with no hiccups, and as illustrated by ICESat-2, NASA has resilient teams that can recover from setbacks.

The Gravity Recovery and Climate Experiment Follow-On (GRACE-FO) mission currently is in operation, measuring mass distribution on Earth. The mission gathered first light in May over the Himalayan Mountains and is now helping to constrain Earth system models with solid data. NASA's collaboration with the National Oceanic and Atmospheric Administration (NOAA) continues to positively impact life on Earth as well, directly affecting weather forecasting. The Suomi-National Polar-Orbiting Partnership (Suomi-NPP) satellite that is used for operational weather forecasting, particularly during the recent active hurricane season, aids in this effort. The partnership aided the Federal Emergency Management Agency (FEMA) as well by providing data on power outages, and pinpointing areas that suffered flooding and tree loss. The heliophysics mission, Ionospheric Connection Explorer (ICON), is due to launch on a Pegasus rocket in early November. ICON has had some challenges on the launch vehicle side, but the spacecraft itself came in below cost and ahead of schedule.

The Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) mission to Mars is due to land on November 26. It is a complicated mission with deployment schemes that are risky. The spacecraft will land on "far side" of Mars. Entry, Descent and Landing (EDL) data will be relayed by two CubeSats, a novel platform that is the embodiment of a technology demonstration. The CubeSat development phase included the participation of many students at California Polytechnical Institute and the University of Michigan. Such work can be life-changing for budding scientists and engineers. The EDL will be a familiar "7 minutes of terror" scenario involving a spacecraft shell, parachutes, and retrorockets. The Global Ecosystem Dynamics Investigation (GEDI) is launching in December and will join one of many observatories on the outside of the International Space Station (ISS). GEDI is a laser coupled with a sizable telescope that will study carbon sinks in the tropics. The Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer (OSIRIS-Rex) spacecraft will arrive at asteroid Bennu on November 30, where it will collect samples from the surface, and New Horizons will fly by a Kuiper Belt object on January 1, 2019. These latter two are very complex missions.

The Miniature X-ray Solar Spectrometer (MinXSS II) will launch on November 20; the mission is a small platform designed to bridge the gap in a spectrum of x-ray measurements. It will act as a bridge between the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI) and Interface Region Imaging Spectrometer (IRIS) instruments. JWST has had well-publicized challenges that precipitated an independent review which yielded a number of recommendations, some related to technology, and many related to leadership and team-building. One of the primary lessons learned is that missions must create processes that uncover small mistakes, to prevent them from rippling outward and engendering large consequences. The JWST team has been effectively rebooted and the launch now is scheduled for March 2021. Dr. Zurbuchen felt comfortable with the team's ability to move forward. SMD continues to engage on the Gateway concept with the Human Exploration and Operations Mission Directorate (HEOMD) to do great science, and expects that benefits will accrue from many disciplines other than lunar science, including astrophysics and heliophysics.

NASA's Commercial Lunar Payload Services (CLPS) is a new opportunity for lunar scientists to put payloads on the Moon. A number of commercial entities are interested in CLPS, and NASA expects to have contracts in place by the end of the calendar year. The astrophysics decadal survey, Astro2020, has had its statement of task finalized, with white papers due in January 2019. The final report should be delivered by early 2021. SMD would like young investigators to have a voice in the process: the more voices heard, the better the process. Dr. Zurbuchen felt that it would be one of the hardest decadal surveys to create, particularly with the status of JWST and the transition of the community.

SMD is developing core principles for a five-year Strategic Plan for Scientific Data and Computing. An October workshop was held with interagency, international and industry (i.e., Cloud providers) participation. A finalized plan is due in early 2019. Dr. Zurbuchen described a recent retreat of the leadership, where SMD brought in amazing people from a broad spectrum of experience to build diverse

teams. NASA is keeping a sharp focus on diversity, ensuring that everyone on the team is safe. This requires that NASA do the things that actively promote an inflow of talent from diverse backgrounds. NASA is looking at diversity through the lens of excellence and aims to retool the environment to improve through this lens. A workshop, Pathways to Mission Leadership, will be held in late November to address the fact that proposals have very few female proposers. Many great ideas are going into the wastebasket due to this phenomenon. Dr. Vinton Cerf asked what sort of percentages were involved. Dr. Zurbuchen reported that Dr. Michael New, Deputy Assistant Administrator for Research looked at 331 mission proposals over 19 years. In that time, only 10% of proposers were female, and most were submitting proposals to the Planetary Science Division.

SMD also is developing a program for spinning-in technologies on robotics and autonomy. A workshop on the technology side of house is looking at this subject. SMD wants to nurture collaboration and partnerships among space and non-space communities. It is known that the industry is making great inroads in robotics and autonomy that NASA could "spin in," and SMD would like to know how to do this better.

Dr. Michael Liemohn asked if there would be call-in participation at the diversity workshop. Ms. Ellen Gertsen said that she was hoping to bring in people for roundtable discussions, and can consider a call-in capability if there is enough interest. Mr. Marc Weiser offered to supply candidate names. Ms. Gertsen asked that representatives of adjacent industries be identified. Dr. Cerf asked Dr. Lori Glaze and Dr. Zurbuchen how NASA was doing in terms of communication capacity. Is it running out of capacity to get data there and back? Dr. Glaze said the issue was not capacity, but the fact that multiple spacecraft are communicating in the same part of the sky. Dr. Zurbuchen noted that NASA is looking at this on a regular basis and recognizes that communications are starting to squeeze against limitations. SMD is partnering with HEOMD to help solve the problem, and has a task force focusing on it.

Dr. Wadhwa applauded SMD's efforts and accomplishments. She asked about possible future ESA partnerships to support Mars Sample Return (MSR), as the effort would require a coalition of the willing, and a process that would extend over both time and budget allocations. Dr. Zurbuchen noted that all Mars stakeholders would be aligned through the decadal survey process, and that Congress has said that NASA should focus on MSR in the late 2020s. ESA ministers will go through a similar process and see how their funding is allocated. The 2019 budgets will be informative, and the process will be parallel in various elements. Landing site selection also will be informative.

Goals of Meeting

Dr. Wadhwa reviewed the goals of the meeting, one being discussions with the Division Directors (DDs) on the status of their relevant decadal surveys. She pointed out that there also are pertinent Space Studies Board reports, exoplanet and astrobiology science strategy documents in particular, and expressed interest in how the DDs are folding in their priorities. Other goals were a discussion about diverse teams and safe environments, discussion on autonomous solutions, detailed briefing on JWST, reports from the advisory committee chairs, and outbrief to Dr. Zurbuchen.

Decadal Surveys: Status and Interdivisional Approaches

Astrophysics Decadal Survey

Dr. Paul Hertz, Director of the Astrophysics Division (APD), reviewed the three questions that drive science activities in astrophysics: How did our universe begin and evolve; how did galaxies, planets and stars come to be, and; are we alone? These questions have been emphasized in all five astrophysics decadal surveys over the last 50 years, and NASA has been answering these questions systematically and scientifically. Other governing documents include a Strategic Plan, Science Plan, the decadal midterm assessments, a 30-year roadmap, and biannual implementation plans, the purposes of which are to

communicate clearly to the community what NASA is doing with the decadal survey. Each of the past surveys has recommended a large space telescope. These are: HST, Chandra, and Spitzer, all of which are still operating and all of which have informed science. The next two DS-recommended telescopes, JWST and the Wide Field Infrared Survey Telescope (WFIRST), will carry on how NASA understands the fundamentals of the universe. The Astro2020 Decadal Survey is anticipated to be ambitious, and not incremental, and to lead to paradigm-shifting discoveries. APD is considering large and medium-sized missions for decadal survey planning. APD is sponsoring four large mission studies, each with a Science and Technology Definition Team (STDT) partnered with NASA engineering centers to lay out estimates. The Division is also supporting, to a much lesser degree, PI-led teams that will organize science teams to lay out concepts at for the mission design laboratories for Probe missions. Independent cost estimates will be done at NASA cost centers.

The National Academies of Science (NAS) Committee on Astronomy and Astrophysics (CAA) issued a report on NASA's preparations for 2020; APD will be implementing all seven of the CAA recommendations. The Astro 2020 Statement of Task is now posted on the Astro2020 home page [https://nas.edu/astro2020]. There will be an Astro2020 Town Hall meeting at the January 2019 AAS conference. The Statement of Task includes an overview of science, and an assessment of the state of the profession. The assessment is not usually included in other surveys; NASA will be paying for publication of this latter part. Additional guidance will be included on planetary and heliophysics science, particle physics, and gravity waves. APD recently received a Congressionally-required Academies report on exoplanet strategy; this study will serve as additional input to the DS. Dr. Hertz felt it was an excellent study, providing the deep dive that perhaps a decadal survey panel would not have had time to do. Near-term, mid-term and far-term recommendations were made: near-term recommendations deal with JWST, research coordination networks, and a robust Research and Analysis (R&A) program. Mid-term recommendations were to keep on with WFIRST, build large ground-based telescopes, and work with the National Science Foundation to figure out how to measure the radial velocity (RV) of stars that are needed to detect Earth-type planets around them. The current barrier is the noise in the stars; the problem is to find out how to subtract this noise. Far-term, the study report recommended that NASA lead a large strategic direct-imaging mission capable of measuring the reflected light spectra of temperate terrestrial planets orbiting Sun-like stars. Dr. Cerf noted that objections to the Thirty Meter Telescope (TMT) on Hawaii's Mauna Kea had been overcome. Dr. Hertz agreed that this was a step forward, and cited interdivisional opportunities for other disciplines, as APD funds and operates telescopes for the entire community through open calls to all divisions, and to all scientists worldwide. Scientists of all disciplines can apply and go through merit-based peer review to access NASA's fabulous capabilities. Asked what fraction of telescope time gets devoted to other disciplines, Dr. Hertz estimated the cross-disciplinary time at about 1-2% for HST, and as high as 10% for assets such as the Stratospheric Observatory for Infrared Astronomy (SOFIA). He added that peer review panels have planetary scientists on board for planetary proposals, etc. The pressure on observing times stems from proposal numbers, and not bias. In the planetary realm, HST has been imaging Europa for plumes, observing Jupiter aurorae to complement Juno's *in-situ* measurements, and has imaged the region around the Kuiper Belt object that New Horizons will be flying through. Similarly, HST imaged the debris field around Pluto before the New Horizons fly-by and incidentally discovered four new moons. HST also regularly observes aurorae throughout the Solar System, as well as asteroids and comets. The Chandra telescope observes high energy phenomena throughout the Solar System, while SOFIA observes occultations by Solar System objects, and global methane on Mars. The Fermi telescope can observe solar activity. The Spitzer telescope has imaged near-Earth asteroids, and Kepler studied Neptune and Titan when they were within its field of view. TESS, with its 30-minute cadence, will see many moving objects.

Interdivisional R&A is any research that addresses NASA science goals that can be shared among all the SMD divisions. In the Theory program, APD coordinates programs with HPD to ensure that proposals address physics problems common to both astrophysics and heliophysics. Dr. Anne Verbiscer asked if

Science Definition Teams (SDTs) are formed under FACA rules. Dr. Hertz affirmed that this was so, adding that SDTs are chartered as subcommittees under the division advisory committees. Asked if there were formal plans for Planetary Science Division to have input into the Astro2020 document, Dr. Hertz said this had not been discussed explicitly in the Statement of Task but that he has communicated with them on how to incorporate planetary input.

Planetary Science Decadal Survey

Dr. Lori Glaze, Acting Director for PSD, presented a briefing on *Visions and Voyages for Planetary Science in the Decade 2013-2022*, the recent NAS midterm report on decadal survey progress in planetary science, which was released in August of this year. PSD has concurred with the 24 recommendations put forth by the report and is preparing a response. Dr. Glaze offered some major highlights: increase the launch cadence in the Discovery and New Frontiers program, with the intent to release an Announcement of Opportunity every 2-5 years, and a goal of two selections each time. The report issued several recommendations on cost and cost risks. In R&A and Technology, PSD is largely following or exceeding the report's recommendations. The report also detailed missions to be studied before next decadal survey, including a variety of recommendations related to Mars, in particular the forging of a clean and focused joint architecture for MSR between NASA and ESA, and on a communications architecture designed to bolster older communications assets at Mars. The Mars Atmosphere and Volatile EvolutioN (MAVEN) satellite, for example, will be moved to ensure a communications pipeline for the Mars 2020 mission. Dr. Wadhwa asked if there were lessons learned on cost projections from the previous decadal survey. Dr. Glaze said that one was that the last decadal survey had been formulated over too short a timeframe to allow effective cost estimates. This time, PSD is looking to conduct some selected cost studies well in advance. In addition, PSD will respond to an astrobiology study released by NASA recently, which offered a variety of recommendations that emphasize interdisciplinary and cross-divisional work, missions that explore subsurface environments (i.e. Icy Worlds, beneath Mars ice caps), and determination of agnostic biosignatures that would make as few assumptions as possible about the types of molecules that actually indicate life's presence. Dr. Pat Patterson asked if there were any efforts in developing starlight suppression techniques for discovering exoplanets. Dr. Hertz explained that the one problem for exoplanet detection is that sufficient aperture size is needed to accumulate enough photons for spectroscopy.

The midterm report's recommendations on cross-divisional collaborations include assessing the role and value of space-based astronomy for planetary science. As one example, the Near Earth Object Widefield Infrared Survey Explorer (NEOWISE) mission had been transferred to PSD from APD in 2010, and has since characterized more than 50 potentially hazardous asteroids. NEOWISE will likely last another winter, but at some near-future point it will get too warm for continuing operation. Dr. Wadhwa asked if PSD had examined AOs to see if there are any barriers keeping interdivisional proposals out. Dr. Hertz noted that former APD Director Dr. Anne Kinney had looked at HST proposals and found that selection rates were similar across disciplines, but that action did result in an increase in outreach to PSD to raise awareness. He added that HST does extraordinary planetary work, as evidence previously presented shows, noting the Outer Planets Atmospheres Legacy (OPAL) program in particular. Dr. Glaze confirmed this effort, as did Dr. Verbiscer.

The ground-based facilities, Infrared Telescope Facility (IRTF) and the Keck Observatory, are exemplary of interdivisional collaboration. The Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) has also been a workhorse for discovery of near-Earth asteroids. The planetary community is excited about TESS for the discovery of terrestrial exoplanets, and continued measurements from MAVEN in characterizing the outer atmosphere of Mars. In R&A activities, there is much overlap between PSD, HPD, and HEOMD via the Astrobiology Institute and the Solar System and Solar System Exploration and Research Virtual Institute (SSERVI). In particular, the Nexus for Exoplanet System Science (NExSS) was called out by the National Academies as an excellent model of collaboration across

science divisions. The NAS Astrobiology report recommends that PSD continue to build on the NEXSS model. In preparing for the next planetary decadal survey, the Division has started mission concept studies on the asteroid Ceres and an architecture for MSR. PSD is considering conducting remaining studies through a competed ROSES opportunity for science teams, to ensure more input from the community. The final reports from these efforts, along with cost estimates, will be used as input to the decadal survey.

In the interest of time, Dr. Wadhwa moved Dr. Michael Freilich's ESD decadal survey status briefing to the next day.

Heliophysics Decadal Survey

Dr. James Spann presented in lieu of Dr. Nicola Fox for the HPD, which is in the process of preparing for a mid-term review that kicks off in 2019. The next survey is expected to align with the 2013 Heliophysics Decadal Survey, which had four primary recommendations. HPD is completing the current program and held a Senior Review last year for its operating missions. This year has also been a busy one in carrying out the remainder of the decadal survey missions, including the launch of the Parker Solar Probe (PSP), ICON, and the development phase of Solar Orbiter. The Diversify, Realize, Integrate, Venture, Educate (DRIVE) initiative has been fully implemented, beginning in 2015, and has had a big impact on HPD's R&A and technology development programs. In addition, the Division has been accelerating and expanding the Heliophysics Explorer programs; its notional mission cadence will continue to follow the decadal survey going forward. The Solar Terrestrial Probe (STP) program is in the process of being restructured as a moderate program. A final STDT report on the Geospace Dynamics Constellation (GDC), a Living With a Star (LWS) mission, is expected early in 2019. HPD is planning to launch Solar Orbiter no earlier than February 2020.

In STP, the next reference missions are Dynamical Neutral Atmosphere-Ionosphere Coupling (DYNAMIC) and Magnetosphere Energetics, Dynamics, and Ionospheric Coupling Investigation (MEDICI). A mid-sized Explorer (MIDEX) Announcement of Opportunity (AO) is planned for 2019. Current heliophysics strategy and planning documentation includes development of a roadmap, and direction through National Space Weather Strategy. There is also a directed space weather component to NASA field Centers: the Community Coordinated Modeling Center (CCMC) at Goddard Space Flight Center and High-End Computing (HEC) at Ames Research Center. The Space Weather Science Applications Program will establish an expanded role for NASA in space weather science under a single budget element. NASA is also emphasizing three areas in cross-disciplinary science through a "Whole Helio" campaign, to include planetary science that will be driven by the PSP perihelion passes; an expanded rideshare program on heliophysics launches; and activities with the HEOMD Gateway. Dr. Wadhwa asked if other division missions were being thought of more broadly in this way. Dr. Spann indicated that absolutely yes, SMD will engage other missions, such as Magnetospheric Multiscale (MMS), or Lagrange Point 1 observatories, or observations being taken at Mars, to get a snapshot of the entire system.

Technology development for the heliophysics rideshare is focusing on establishing standard practices to maximize mass to orbit. For example, for the Interstellar Mapping and Acceleration Probe (IMAP) launch in 2024, HPD has an open call for a rideshare on the launch vehicle's Evolved Expendable Launch Vehicle (EELV) Secondary Payload Adapter (ESPA) ring. This call will include at least one science Mission of Opportunity (MoO), a small complete mission, and one technology demonstration. The goal is to have the agility to respond quickly, and to solicit high technology readiness level (TRL) investigations. With respect to the Gateway, HPD sees unique opportunities to study geospace and the coupling between the Earth's magnetosphere, ionosphere, and upper atmosphere, and perhaps some solar observations. Interdivisional R&A activities are actively looking for cross-divisional opportunities on CubeSats,

Sounding Rockets, and balloons. NASA and NOAA continue their interagency collaborations in space weather through active memoranda of understanding.

Dr. Cerf asked how confidently coronal mass ejections (CMEs) could be predicted. Dr. Spann answered that at present, the Earth has about one or two days to prepare for an observed CME. Studies compiled by Lloyd's of London treat the probability of a CME like a "hundred-year" flood; it's not a question of if but when. Preparations for such events depend on the industry. The power industry, for one, looks at ways to redistribute power lines in grids. Communications on the day side are another issue. The Department of Defense (DoD) takes the issue very seriously due to its various dependencies. The National Space Weather Plan also takes CME preparation into account, and it is why there is a new emphasis at NASA to provide the operational side of the government the decision-making tools. At present, NASA is very much focusing on transitioning to operations. Asked about the process for selecting missions for HP rideshares, Dr. Spann said the standard proposal process is the means, and that there is a Stand-Alone Mission of Opportunity (SALMON) call right now that will close at the end of the month. HPD generally lets the community know in advance. He estimated that there were 5 ports on the ESPA "Grande" for IMAP, which may or may not get filled to capacity.

James Webb Space Telescope Update

Mr. Greg Robinson, JWST Program Director, provided a status of the mission. The Spacecraft Element (SCE) has restarted environmental testing, and is currently in acoustics re-test. No loose hardware has been found during this round, indicating good progress. Vibration testing should start within two weeks. An Independent Review Board (IRB) conducted a review of the mission in April 2018 and issued 32 recommendations, and NASA has accepted every one. The IRB will revisit JWST at the end of November to assess the implementation plan, receive an early outbrief before the holidays, and issue a full report shortly afterward. The IRB will have an interim review in March 2019. JWST lessons learned have been completed and documented, and may be briefed at an Agency Program Management Council (APMC) any time between November and January. Since the last meeting of the SC, Mr. Robinson reported that the mission has designed and added "bumpers" to mitigate the problem of loose screws, an activity that consumed four weeks of schedule reserve. In addition, the mission did "reach-across" audits on drawings and procedures to eliminate "embedded problems" and scrubbed 800-plus areas before returning the SCE to the testing process. Very few problems were found during this process. There are still minor concerns about fairing pressurization that are currently under analysis; the team is looking at the vents on the fairing to see if they can be kept open longer, and is working with the builder and ESA on mitigating the concern. Mr. Robinson thought the issue would be resolved in the next few weeks, as it was trending in a positive way.

One of the IRB recommendations was that the Launch Services Program (LSP) should be accountable for the success of the launch vehicle. JWST is trying to meet the intent of the recommendation by meeting with the Ariane V team (ESA and the vendor). In the area of communications, the IRB felt that results differed by level of reporting, thus as JWST gets closer to launch, the team is ramping up coordination of all the players. The mission will brief Dr. Zurbuchen just before Thanksgiving, and is also doing a weekly tag-up with NASA Associate Administrator Steve Jurczyk, the Program Managers (PMs), the Centers, as well as Dr. Zurbuchen. The mission has a biweekly telecon with Northrop-Grumman and has since added more people to the call. The JWST Science Working Group (SWG), led by Dr. Eric Smith, which meets three times per year face-to-face and holds a weekly telecon, provides a good discussion of mission challenges. The IRB also felt that JWST needed a commissioning manager working across the program; this manager has one job, and the authority to pull the right teams together, addressing "what-ifs" across the whole system.

Human factor recommendations from the IRB include ensuring that the appropriately trained people are employed at specific operations, such as the unfolding of the sunshield, and that the right inspectors are

present at procedure developments and updates; i.e. more NASA folks on site. Mission Assurance personnel must also be present at test readiness reviews. Test-As-You-Fly practices have been implemented for some time. The IRB also had some concern about transportation and threats to security at the time of shipment. NASA will consult DoD at approximately one year before transport to obtain a threat assessment. Other mission operations and mission success recommendations have been addressed and closed either by active response or by processes already in place. Schedules have been mitigated to address overwork. To improve morale, the mission is considering having scientists come out and give talks on the significance of the project. Mr. Robinson detailed items on the master schedule, and said there would be a Systems Integration Review in August 2019, and that Headquarters is holding four months of schedule reserve.

Note: Given conflict of interest, Dr. Kathryn Flanagan recused herself for the entirety of the JWST discussion.

Dr. Cerf asked if there would be a full-up test of the system in deployed form. Mr. Robinson noted that the telescope's sunshields are tennis-court sized, and that there is no way to do full-scale testing. Dr. Tamara Jernigan indicated that there are certain things that can't be tested in one gravity, and pointed out that NASA managed to get the entirety of the International Space Station (ISS) into orbit without full deployment testing. Dr. Eric Smith, Program Scientist for JWST, added that JWST's entire optics suite had been tested at Johnson Space Center in a simulated environment. Dr. Cerf asked if it were possible to fully deploy and re-fold the sunshield. Mr. Robinson said that the sunshield had gone through multiple unfold-and-stow activities, and that this test would be carried out several more times to bolster confidence levels. An end-to-end communications test also will be done, as with all missions. Dr. Smith said that commands to the spacecraft from the Space Telescope Science Institute (STScI) in Baltimore have already been verified. Dr. Michelle Larson suggested that JWST consider a community and family event to help personnel gain an appreciation for the project, and to have some of the workers integrated into the demonstrations. Mr. Robinson welcomed the recommendation, adding that he had considered a family day at Northrop-Grumman. Mr. Weiser asked if anyone had looked at the mission issues from tactical and strategic standpoints, as these lessons learned could be used in the next decadal survey. Mr. Robinson said that the lessons learned had not yet put into buckets, and noted that a third area, execution, also would be helpful. Dr. Wadhwa noticed that some human factors recommendations still appeared to be open and asked if there were potential threats there. Mr. Robinson said that most if not everything the mission has put in place have helped to mitigate these latter recommendations, and that sometimes actions are kept open just as a bookkeeping item. He added that the recommendations that are still open or that need to be re-addressed are always under discussion.

Psyche- Journey to a Metal World

Dr. Sarah Noble and Ms. Diane Brown presented a short video on a new mission in the Discovery program, Psyche, an asteroid thought to be almost entirely metallic. A Psyche-inspired art book published by NASA was circulated. NASA also is planning a contest that invites artists to imagine what Psyche will look like. The mission is currently in Phase B and is scheduled to launch in August 2022.

Division Advisory Committee Reports

Planetary Science Advisory Committee

Dr. Anne Verbiscer, Chair of the Planetary Science Advisory Committee (PAC), reported that the committee had had its first face-to-face meeting in February, followed by two telecons in July and September 2018. The PAC received a status report from PSD Acting Director, Dr. Lori Glaze, and a report on R&A status. In response to a request for a report from the Planetary Defense Coordination Office (PDCO), PSD presented a report via Dr. Kelly Fast, in which she reviewed progress in meeting requirements for identifying near-Earth objects, the status of NEOWISE, and the development status of

the Near-Earth Object Camera mission (NEOCam). The Senior Review process has been changed for PSD and will now be done as a FACA exercise under the PAC. To that end, the PAC issued a finding that formally approved the terms of reference (TOR) for the new Senior Review process, and also completed the annual Government Performance and Results Act (GPRA) task, voting Green on all elements. Recent PAC findings included one on linking PSD-funded research to publication, a discussion that arose from the GPRA process. PAC felt that NASA's science contributions were going unrecognized and could be better represented and publicized. PAC also issued a finding on review panel honoraria, which NASA has since substantially increased. Dr. Verbiscer noted that there are a number of people who remain unable to accept honoraria, and that the PAC would like to see ways in which this can be addressed. The PAC is concerned about conflicts of interest in upcoming Senior Reviews, and found that sustainability of quora may be interrupted by this situation. The PAC found that Terrestrial Analog and Impact Cratering Studies are not being supported by the current R&A reorganization. PAC issued a finding applauding NASA's policy statement on anti-discrimination; the PAC supports it and wishes the statement was even stronger, to include professional harassment (such as bullying speakers during Q&A sessions). Dr. Michael New commented in this context that NASA is guided by Federal civil rights laws, and he did not think that there was a class of protected persons in this characterization. However, if bullying *per se* was the issue, he noted that there has been discussion of this in the review panels.

In a review of science highlights, Dr. Verbiscer reported that the PAC is anticipating the successful landing of InSight, a New Horizons flyby, and the arrival of OSIRIS-Rex at Bennu. Dr. Wadhwa asked how "science nuggets" from the GPRA process could be better broadcast. Dr. Verbiscer noted that one proposal, according to PSD's Dr. Jonathan Rall, has been discussed; i.e. using a system modeled on what the National Science Foundation (NSF) uses for fast-lane reviews. To do this, NASA would have to modify NSPIRES to allow Program Officers (POs) to pull out the relevant data. Dr. Wadhwa thought that might be worth a discussion across all the SMD committees. Dr. Verbiscer added that one other way might be having NASA POs track publications that come from their grants. Dr. New noted that many POs already do this, and that the GPRA process is often a last-minute exercise. He agreed that NSPIRES is in need of a major upgrade to accommodate these reports, which will require new software code. Dr. Liemohn said that the Heliophysics Advisory Committee (HPAC) has similar sentiments about GPRA information, and that as journals are moving more to metadata, it takes a lot of time to upload publication data. Dr. Wadhwa flagged this as a possible issue for further discussion.

Heliophysics Advisory Committee

Dr. Liemohn provided an update on HPAC, where he indicated that its discussion of possible Senior Review conflicts of interest had resulted in getting the General Counsel involved in the process, to ensure proper conduct in accepting the report. He hoped that such an approach might work for the PAC. HPAC completed its GPRA exercise over two telecons and rated all three annual performance indicators (APIs) as Green: physical progress; Sun-Earth connections; and space weather. Science highlights included recent data on the physics of spicules, small bright regions in the lower corona of the Sun. Solar Dynamics Orbiter (SDO) and IRIS observations combined with modeling have shown that spicules are a primary mechanism for heating plasma to coronal temperatures. Aeronomy of Ice Mission (AIM) data on lower atmospheric influences on upper layers have shown that atmospheric gravity waves transmit energy from the Earth's lower atmosphere into the middle and upper layers. Data from the Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED) mission have shown that upper atmospheric heating during magnetic superstorms can change the chemical composition in some layers of the upper atmosphere; e.g., ratios of atomic oxygen to molecular oxygen.

Astrophysics Advisory Committee

Astrophysics Advisory Committee (APAC) Chair Dr. Feryal Ozel presented an update remotely. The committee's last face-to-face meeting took place in July, and its last telecon was held in October. APAC hears from the JWST at every meeting, and issued a finding stating that JWST has been adhering to

recommendations. APAC further found that while the launch delay may have science impacts on the community, it was assured that there were no remaining significant challenges in this area. Dr. Ozel noted that she and many other APAC members have conflicts of interest on WFIRST, and careful steps were taken in reporting on it. There have been significant changes to the coronagraph and to the survey. The coronagraph is now a technology demonstration, and a ground-based component has been added to the mission to complement the survey. The Neutron star Interior Composition Explorer (NICER) instrument on ISS is entering its Guest Observer (GO) program, for which the APAC heard first results. The Imaging X-ray Polarimetry Explorer (IXPE) mission is entering phase C. A Small Explorer (SMEX) AO is planned for Spring 2019, while an APD MIDEX is on target for downselection in January 2019. APD is also going to conduct a Senior Review of all its missions, save for SOFIA, per Congressional order. SOFIA is at the end of its five-year lifetime and will undergo a science review. APAC has been concerned about SOFIA's science output. APAC is pleased with progress on planning for the Astro2020 Decadal Survey. Four large mission concept studies have been ongoing for two years, as well as smaller Probe studies, both of which will serve as survey input. The APAC expressed approval of plans to conduct external cost review of these studies.

APAC issued some findings on the status of HEC at NASA, pointing up the continued need for new computing resources, and the fact that there is an increasing fraction of computing time that is going unused due to challenges in queuing and user habits. APAC recommends that there be a continued effort in better queuing of algorithms, and continued expansion of computing resources. A two-step time allocation model slows things down; APAC recommends some changes to the model, and also recommends community education in upcoming conferences, such as the American Astronomical Society (AAS). APAC has also been discussing obstacles to intradivisional science and is preparing a survey, to be conducted through the three APAC Program Analysis Groups (PAGs), to determine what science might be falling through the cracks. APAC will take up the discussion again in May 2019 and report results thereafter. APAC conducted its uniformly positive GPRA review in July and is also continuing to monitor NASA's Internal Science Funding Model (ISFM), having heard the latest statistics that confirm that ISFM has not affected the funding and balance of the program both inside and outside of Centers. Dr. New commented that the SMD divisions have implemented the ISFM differently, and that SMD will issue an implementation guide shortly to standardize the guidelines across SMD. Dr. Wadhwa requested a report on how uniform guidelines are being implemented in ISFM, and impact is being monitored. Dr. New took an action to respond to the request. One last APAC concern focused on the "leaky pipeline" career issue that is currently being examined by Dr. New through a longitudinal study on career paths leading to successful outcomes.

Earth Science Advisory Committee

Dr. J. Marshall Shepherd, Chair of the Earth Science Advisory Committee (ESAC), presented the ESAC report, beginning with key news items: on September 28, NASA awarded sole source contracts to acquire test data from three private sector organizations that collect Earth observation data. He acknowledged the October decommissioning of the SeaWinds scatterometer on the Quick Scatterometer (QuikSCAT) spacecraft. The instrument had served as a gold standard against which new spaceborne scatterometers are measured, providing high-resolution data on ice, and new indicators for hurricane intensity, such as measurements of cold cloud tops. During the 2018 hurricane season, the Global Precipitation Measurement (GPM) mission instrument provided information on rapidly developing "hot towers," another signal for storm intensification. These data may improve intensity forecasts. The Suomi NPOESS Preparatory Project (NPP) satellite also aided hurricane recovery efforts by locating areas of outages and helping responders to restore power.

ESAC made a number of findings and recommendations on the decadal survey, many of which are fully under way at the Earth Science Division (ESD). ESAC completed the GPRA for ESD and rated all six APIs as Green. The ESAC Chair will brief the Space Studies Board (SSB) on November 7, and the next

ESAC meeting is scheduled for the January-February timeframe. Dr. Michael Freilich, ESD Director, is retiring in February; the position is now posted on the USAJobs website. Asked whether Dr. Shepherd had any comments on the decadal survey, he said that many in the community had been accustomed to a mission-focused approach. He was not sure what Dr. Freilich would have to say about how to meet core research questions. It is recognized, though, that one can achieve multiple goals within each research question, thus the community needs to better understand challenges and opportunities in the new decadal survey approach. Dr. Shepherd closed the discussion by mentioning that Hurricane Michael may be re-categorized as a Category 5 storm, as oftentimes an initial categorization is based on preliminary dropsonde data. There also is the Dvorak technique which is based on a satellite signature; some of the data based on the technique's "t" numbers suggested it was a Category 5.

Public Comments
No public comments were noted.

Discussion
Dr. Wadhwa opened a discussion about decadal survey interdivisional research efforts. Dr. Cerf expressed concern about data curation and preservation and commented that he would like to see some private sector engagement in ingesting and processing data. Mr. Weiser noted that new space industry players are now replacing engineering cycles that were once the purview of NASA, and wondered if NASA had engaged industry as part of the decadal survey planning process. NASA has many outside partners now, aside from the usual large contractors. Dr. Cerf suggested that NASA help scientists to understand what the private sector is capable of doing, as new sorts of mission designs may not be obvious. Dr. Liemohn agreed and felt it important for NASA take a strong lead here. Mr. Weiser noted that there are start-ups that are looking at 25-plus kilo packages to be kept geostationary for months on end.

Dr. Larson aired the thought that NASA might need a reward system for interdisciplinary work, or some sort of acknowledgement. Dr. Patterson thought the discussion on Gateway science was very promising, and wondered if the decadal survey would suggest or request things from Gateway, such as magnetic cleanliness, or vibrational requirements to support certain instruments. Dr. New said that SMD was already closely engaged with HEO on these issues, and that the engagement is continuing. Contamination and magnetic cleanliness are definitely issues. Vibration is less of an issue, given that packages on ISS usually have vibration damping, jitter and noise adjustments built in. Dr. Verbiscer said she would like to see planetary input into Astro2020 formalized in a Statement of Task. She further noted that the planetary mid-term report did address commercial partnerships. Dr. Ozel added that there also is the interagency aspect; more astrophysics missions need ground-based support, and there are currently few formal agreements to make that happen. Dr. Liemohn said he would like to hear more about collaborations at a smaller scale. Dr. Flanagan commented that there is some clearly interdivisional work that doesn't quite fit into existing AOs, as in the overlap between astrophysics and planetary. At the decadal survey level, she agreed that overlap and input are good things. However, a recommendation for a big mission that overlaps all three agencies might in itself bias that mission toward selection. Another issue is that NASA tends to "staircase" with ESA, thus it's a good idea to include an ESA representative on the decadal survey panels in relevant domains, to think strategically with both Europe and with industry. Dr. Ozel very much agreed that bias can be injected into the decadal survey by involving other agencies, and that the community should just be aware of it on some level.

In other notes on possible findings and recommendations, Mr. Weiser suggested separating tactical vs. strategic lessons learned with respect to JWST. The SC also discussed ways to standardize and streamline the GPRA process, and perhaps including weblinks to sources in the reports.

Asked whether HEC recommendations from APAC are being covered in the Data Management Strategic Plan, Dr. Zurbuchen said SMD was trying hard to get talent from the user community, and felt that APAC

is focusing on the right question: what is the strategy on computing? He also thought it was important to look at in terms of data and computational abilities, as some communities are at a technological status of 30 years prior. Infrastructure is informed by old code, and the issues APAC has flagged should be elevated to attention of the strategic management team on data. Dr. Shepherd noted that the HEC issue had arisen at the end of last ESAC meeting, and that it would be a subject of discussion at the next ESAC meeting. Dr. Liemohn said that the Department of Energy (DOE) monitors burn rates for its HEC users very closely; SMD is just starting to do this. DOE also allocates a small amount of resources to do test runs, to ensure the code will work before the project starts.

Dr. Liemohn commended SMD's upcoming diversity workshop, and Administrator Bridenstine's anti-harassment memo, and wondered how SMD is reacting to these changes. Dr. Zurbuchen noted that these changes emerged from SMD and enjoyed immediate and strong support from the Administrator. He added that NASA recognizes that these are not "one and done" issues.

November 2, 2018

Diverse Teams and Safe Environments

Equity and Inclusion in STEM: Where We Are, Why, and How to Get to Parity

Dr. Meg Urry presented a briefing on improving science through broadening the community. Discrimination against minorities and women cannot be addressed without having them at the table. From 1965 to 2015 the percentage of women earning doctoral degrees has increased to 50%, with engineering and physics in last place, which is stalled at about 20%. Physics and engineering are important fields for NASA; the number of women in physics is increasing but the number of men is increasing faster. From 1991-2010, the percentage of STEM degrees conferred on black and Hispanic women is very low; the number of doctorates in astronomy and physics is vanishingly low, about a handful per year. In terms of differential attrition in STEM fields, 57% of bachelor's degrees going to women are followed by only 46% of Ph.D.s going to same. For physics, there is not much attrition, roughly 20% of both bachelor's degrees and Ph.D.s go to women. For engineering, there is a slight uptick from bachelor's to Ph.D., and in biology and chemistry, the differential drop is at the post-doc level. In hiring, there are fewer than 20% female assistant professors in biology and fewer than 10% in chemistry. Why aren't these numbers at 50%? Persistence in science is not correlated with ability, interest or effort. Women do just as well in these classes as men, however they tend to think they are not doing as well. The difference also is not a family issue; there is no difference observed when comparing women with or without children. Scandinavian countries have high family benefits but in that area of the world, the physics discipline is comprised of only 10% females. While conscious discrimination is muted compared to the past, it appears that society still has lower expectations of women, as women tend not to be seen as leaders in society. Women are rated lower even with similar qualifications to men, according to numerous resumé studies. Hiring firms tend to pick the people who look like the people who were there before. There is also an accumulation of disadvantage, even if the disadvantages are very small. Dr. Urry recommended consulting the https://implicit.harvard.edu/implicit/program for testing unconscious biases.

Career stages are filters; every criterion for evaluating scientists has been shown to be biased by gender. Even at institutes known to exhibit good will to women, e.g. STScI, this bias persists. Letters of recommendation differ greatly between men and women in terms of wording and description. The playing field is not level, but the tilt can be leveled if one is conscious of the fact. How to get to parity? There are some identified best practices: develop criteria in advance; judge applications against criteria; if at all possible, remove names from applications (STScI is experimenting with this approach); if it is not possible to remove names, include more than 30% women in the candidate pool; do not rank until a joint discussion has been held; and educate colleagues before a candidate visit or interview. Affirmation also

works: it is important to actively support women's voices. A man and woman giving the exact same talk are judged differently. Some ways to do this are: provide detailed introductions for female speakers (pre-validation), and make strong appointments that affirm this validation.

Coaching and mentoring also are important for women. Dr. Urry relayed an anecdote about a women's soccer team that won the World Cup. In an interview, the team's coach pointed out that when he coached the women the way he coached men, they played poorly. When he switched from criticism to affirmation as a coaching tool, the female team played at World Cup level. Dr. Urry commented that it's hard to tell what people need, thus it is necessary to match mentoring to what the mentee needs. To move to true equity, there are hurdles that must be consciously and actively removed. Only when equity is achieved will there be parity. Dr. Urry further noted that harassment became very visible to her when she served as president of the AAS. During her tenure, she found that both men and women trainees experienced very high levels of harassment or assault in the field. Sources of unwanted contact differed, however: for women, it was mostly superiors, and for men, it was mostly peers. This is a striking difference. Institutions should create rules that prevent faculty, in particular, from looking at their students as potential romantic partners. NAS, NASA, and other organizations are starting to make inroads in this area. Dr. Urry closed by pointing out that, contrary to what some believe, affirmative action actually raises standards, and does not lower them.

Dr. Cerf expressed alarm at the low participation of women in computer science. Dr. Urry noted that in the 1980s, women were very keen to enter the field. This decade was quickly followed by a dropoff; some of this effect is thought to be due to an influx of foreign students who were mostly male, and the other was "bro culture" (hazing, sleeping at the office). In speaking with many students over the years, Dr. Urry found that it's always the culture, and never the material, that keeps females out of STEM disciplines. Dr. Cerf related an anecdote about a U.S. Military Academy female professor, who always ensured that there were at least three women in her class. A Deputy Director of the Computer Science department also coached the rowing team, where he heard insults like "you row like a woman." When he insisted on mixed training sessions, that sort of contempt disappeared. Dr. Ozel added that affirming women in meetings goes both ways; senior women should speak up so that younger women can feel comfortable in following their lead. Dr. Urry noted that in academic Q&A sessions, it has been found that it is far more likely that when a woman speaks first, other women will speak too. Dr. Liemohn agreed that bro culture is a problem, and that anti-female idioms are built into daily speech. Dr. Shepherd pointed out the use of colloquialisms in the discussion (gal, etc.), and that everyone must check their own habits. Dr. Wadhwa agreed, using "manned" space flight as another example, versus crewed and un-crewed; the adjective "manned" is still very prevalent in major publications. Dr. Urry brought up a ten-year-old study in which men's physics study groups were asked why they didn't want females in their group; they answered that they only wanted the "best." When pressed for proof that females were not the best, they couldn't justify their opinions. Even women are more or less biased against women in STEM. Dr. Wadhwa noted that many institutions go through implicit bias training, and asked if there were any statistics on the efficacy of this type of training. Dr. Urry said that most studies show that this sort of training doesn't work well and that it is very hard to get scientists to admit their own bias. Dr. Walter Secada suggested that NASA could institute mentoring at the post-doc level, to help junior faculty climb to leadership positions. Dr. Jernigan asked if there were metrics on the impact of bias training. Dr. Urry said that the few studies that have looked at the effects of training conclude that people seem to resent the training itself. Dr. Liemohn observed that bystander intervention training should be effective because the participants are actually willing participants. Dr. Larson noted that "upstander," a term used by the Illinois Holocaust Museum, could be a more illustrative name for a bystander that is attempting to improve a situation. Dr. Flanagan felt that peer-to-peer interaction could be especially effective, as the discomfort of peer disapproval is high.

SMD Actions and Research

Dr. New, Deputy Associate Administrator for Research, gave a briefing on the status of the SMD Research program. The Research program has a new focus on fostering a community where everyone feels safe in expressing diverse opinions and perspectives, as diversity fuels excellence and innovation. Encouraging healthy behavior is the first step in moving forward. SMD set out to discover issues in the R&A program, to see whether there were any large-scale gender biases in SMD's grant proposals; there is now a preliminary analysis of data that has been gathered over two years' time. The analysis relies on inferred gender based on first names, and is considered reasonably accurate for European names. Using a program (https://gender-api.com/) that can generate names with a confidence level of 95%. SMD examined 4000 proposals, for which the overall selection rate was 24%. The percentage of inferred female proposal PIs was 20.0%, with no significant variation between science divisions. This first glance shows no obvious bias.

For PI-led missions, SMD analyzed the inferred genders of PIs through open-source intelligence; this analysis examined 344 proposals between 2001 and 2018, for which less than 10% of the proposing PIs were female. This is a stark difference from the R&A program. In the PI-led mission case, 88% of those PIs who were female applied to PSD solicitations (Discovery, NF, Mars Scout); i.e. the percentage of female proposers to PSD was much higher than 10%. The data indicate that there are major divisional differences that are not well understood. It is known, however, that there are two female PIs in Planetary science who have been extraordinarily generous in encouraging other women, perhaps indicating a founder effect in PSD that accounts for higher female participation in this discipline.

In a separate analysis, in response to criticism for not supporting innovative, high-risk, high-payoff fundamental research, SMD did a small study gauging the community's idea of impact vs. intellectual risk. Of 1600 proposals to 2017 ROSES, reviewers rated about 10% of proposals as high-impact, high-risk. Of the 24% of proposals that were selected overall, 35% were rated as high-risk, high-payoff. The review panel process thus seems agnostic to risk level for proposals judged to have high to moderate impact.

There is a new detail position for a Lead for Diversity and Inclusion. SMD has also been consulting with Daniel Kahneman (author of Thinking Fast and Slow) in examining alternate means of selected high-impact proposals. SMD also is partnering with David Chambers of the Office of Diversity and Equal Opportunity; working on implementing new grant terms and conditions based on NSF practices; piloting a Code of Conduct for panelists in an effort to eliminate bullying; an examining barriers to diversity and inclusion within NASA and the broader science community. To answer the question of why there are so few female PIs, SMD is building a database, PI Pathways Database, to see what common patterns pop up, in addition to evaluating the effectiveness of the NASA Earth and Space Science Fellowship (NESSF) program, as preliminary data indicate that NESSF participants complete their Ph.D.s at a higher rate. SMD is also evaluating the Human Outer Planet Exploration (HOPE) program for early and mid-career scientists, piloting PI Diversity Workshops with the Association of American Universities (AAU) in November, and participating with the Office of Small Business Programs' "Road Shows" at select universities. NASA is also taking a policy approach by streamlining Class D missions (under $150M), which throws out a lot of overhead review requirements, and tailoring technical, management, and cost evaluations. Dr. Flanagan felt that it was important to make a strong statement to universities that diversity matters to NASA; somewhere out there NASA is not getting enough proposals. There may be a chokehold at the lower levels, as some institutions can't afford more to fund more than one person on a NASA proposal. Dr. New noted that SMD is trying to do a bit of networking to introduce potential PIs to NASA opportunities. Dr. Flanagan also recommended broadcasting fellowships while making it clear that NASA will be looking at 10-year statistics in the future. Dr. Cerf said he was surprised at the high number of high-impact proposals, and wondered if the assessments were due to confirmation bias. Dr. New noted that conversations about risk tend to be muddled, so there's a caveat on these numbers; SMD is going to

try to continue the data series, and track the progress of selected high-impact, high-risk proposals. Dr. Jernigan appreciated the care and professionalism shown to the subject of diversity. Dr. Flanagan also congratulated NASA on making the effort. The SC affirmed these thoughts collectively. Mr. Weiser noted that the conversation has to be frequent and consistent, even if it's only a short reminder. He reported that he has refused to sit on a panel unless he was assured there was adequate representation of diversity.

Public-Private Partnerships: The Future of Autonomy in NASA Missions

Mr. Michael Seablom, SMD Chief Technologist, introduced a briefing on new efforts to develop autonomous systems. NASA has about 12-15 programs, funded at a total of $200M, to develop new capabilities for science instruments. The Agency is relying on external investments for platforms, while focusing on small-satellite (SmallSat) technologies as these platforms evolve. NASA is actively looking for help from industry and academia. When Dr. Zurbuchen first arrived at SMD, he asked where the Directorate needed additional investments; these areas were identified to be SmallSats, integrated photonics, Data Analytics, HEC, and autonomy. There is much growth in industry for autonomy (e.g., self-driving cars). NASA held an Autonomy Workshop at the Carnegie-Mellon Institute in October focusing on creating design reference missions (DRMs) for the 2030-2050 timeframe. The workshop was well-attended by PMs, POs, and industry. NASA wants scientists to think out of the box, and to "skate toward where the puck is going to be," and understand the state-of-the-art of the industry, to have better science at lower cost and risk.

NASA Autonomous Systems Research and Development

Dr. Terry Fong, Senior Scientist for Autonomous Systems at NASA Ames Research Center, gave a status of research and development (R&D) in autonomy at NASA, noting that Autonomy is not equivalent to Artificial Intelligence (AI). AI is a very broad set of algorithms and techniques, and is involved in such disciplines as machine learning, robotics, speech, machine vision, etc. By one definition given by Andrew Moore in *Forbes*, AI is the "science and engineering of making computers behave in ways that, until recently, we thought required human intelligence." Automation, by contrast to AI, is not self-directed. A system can be automated without being autonomous. Autonomy is the ability of a system to achieve goals while operating independently of external control. Autonomy requires self-directedness to achieve goals and self-sufficiency to operate independently, and requires an ensemble of elements to achieve self-direction (i.e., software, hardware). The Mars Curiosity uses AutoNav to autonomously drive from point to point. Autonomy is not automation but often relies on automation. Autonomy is not only about making systems, adaptive, intelligent, and smart, but also making systems self-directed and self-sufficient. Autonomy requires reasoning about consequences, and the ability to deal with uncertainty. Autonomy is needed when the cadence of decision-making exceeds communication constraints, when time-critical decisions must be made on-board, and when decisions can be better made using rich on-board data. NASA can use autonomy in numerous areas, such as Earth launch and landing systems, ground-based systems, and Earth atmospheric systems. NASA's variety and range of missions makes it challenging to develop common autonomous systems. SMD missions are often unique, with components that are generally one-off or high-value (or both); of high complexity; operate in harsh environments; and rely on limited computing/communications. Autonomy has been used so sparingly to date because of the "unknown unknowns." The real world is a heavy-tailed distribution; i.e. there is a high probability of unexpected events after many years of system operation, or because of many activities taking place in the system. All models are approximations. Computation is not yet instantaneous or infinite.

Autonomy is intricately tied to specific systems and requires many elements such as planning, diagnostics, and automated systems, all working together. NASA has developed an Autonomous Systems Technology Taxonomy: situation and self-awareness; reasoning and acting; collaboration and interaction; and engineering and integrity. Each of the four elements has numerous sub-elements, e.g. sensing and perception under Situation and Self-awareness. At the Autonomy workshop, teams used the taxonomy to develop DRMs. In R&D for future science missions, the teams also identified key areas to make progress

in are: perception for extreme environments (Icy Worlds, planetary voids); reactive science (observe or sample dynamic and transient phenomena, such as plumes, seeps, and weather, with new 3D sensors); and collective operations, such as enabling a spacecraft swarm to collectively perform distributed activities. The latter requires a distributed autonomy architecture, including coordination and collaboration.

Deep Space Autonomy: A Parochial Perspective from JPL

Mr. Robert Manning, Chief Engineer from the Jet Propulsion Laboratory (JPL), and Chief Engineer for Mars Curiosity, gave his perspective on autonomy, having used it for much of his career. He began by citing Dennett's three levels of behavioral abstraction, through which humans view the behavior of an entity. Future behavior is predicted on knowledge of the 1) physical stance, the physical constitution of the system; 2) design stance, the intended purpose of the system's design; and 3) intentional stance, the expectations of the intent of the entity. Autonomic principles are based on going forward, giving intent, a mind's eye, to the thing that is being built. Historically at NASA, there was a fear of non-determinism (1960s to 70s), in which all hardware was driven off a common clock. In the 1980s, there was a strong emphasis on deterministic systems. In the 1990s, the need to adapt to commercial-off-the-shelf (COTS) and local non-determinism, autonomy relied on bounded time execution. In the 2000s, the advent of functions that do not require hard deadlines allowed more flexibility in design, meaning that it was okay to execute at non-deterministic times, as long as the order of execution was preserved. In the 2010s, the level of realized complexity increased exponentially, with growth in JPL avionics and flight software, especially with respect to memory size and processing speeds. Historically, the primary driver for evolution of deep space autonomy has been reduction of risk to ensure mission success. Hardware failures are still a concern, such as failures in harsh radiation environments (Jovian radiation). NASA also wants vehicles to function in the absence of communication. For many years, NASA trusted hardware more than software. Hardware backup to software was required for many early missions. Today, NASA wants to create a mind's eye by putting models inside the machine.

A great increase of guidance complexity was needed for the Mars missions, starting with Sojourner, followed by the Mars Exploration Rovers (MERs), to Curiosity. Behavioral complexity growth in rovers was driven by anxiety about having rovers outside of direct, local control. MERs used stereo imagery to construct a terrain map on-board. For Curiosity, less effort was expended to make it autonomous, which led to a much higher level of operational complexity. For Mars 2020 an effort was made to make it more autonomous in order to speed up sample acquisition time; this required a new addition of on-board imagery and map-based, terrain-relative navigation. The 2026 Europa lander will carry science instruments that are thought of in the same way as any closed-loop sensor. Models of science intent need to be captured on board, and future missions will require near-autonomous mission and fault tolerance. Mr. Manning felt that NASA would successfully conquer new concepts in autonomous systems, as it has done for decades.

Discussion

Mr. Seablom concluded the briefing by describing the output of eight workshop teams. Common themes in their work included the use of multiple platforms, intelligence, fault detection and recovery. These teams will report out on their DRMs in the near future. In lunar operations, the teams are looking at wide-area sampling, autonomy, human-robotic interaction, hazard avoidance, fault monitoring, and diagnostics. For Venus exploration, they are examining multiple long-lived landers and aerial assets. For Earth, studies are taking place in improving numerical weather prediction models and adaptive targeting of measurements. Mr. Seablom hoped to have a workshop proceedings document finalized by March. Once the DRMs are established, NASA will identify gaps and then issue a Request for Proposals (RFP) to industry.

Dr. Cerf commented that in networking, and in interplanetary communication, it is important to get to the point where manual scheduling is less important for communications network operations; some overload

can be taken up by developing better autonomous capabilities. Mr. Weiser suggested that NASA think about the Europa lander in terms of humans backing up autonomous systems, from the beginning of mission design planning. Especially when using machine learning, one mission or vehicle informs the next one to a great degree. Simulation is also critical to the effort; because there are near unlimited resources on Earth, NASA should take advantage of these resources up front. Dr. Fong commented that the only way to test the Europa lander will be through simulation; to that end, SMD is starting an open-source simulator for Europa, to reduce the barrier to participant entry. If NASA wants to increase partnerships, it must create easily accessible tools. Mr. Weiser noted that scenario creation through an open source tool is very powerful. Dr. Cerf said that the idea of intent and situational awareness, and having a notion of current state, is a very powerful concept. It's the one thing that distinguishes AI from human intelligence, the latter of which is characterized by the ability to create a model of the real world based on minimal data. Dr. Liemohn said he appreciated the depth of the briefings.

Mr. Weiser commented that a next step for NASA might be to take its findings on autonomy to the big and small players in Silicon Valley. Dr. Zurbuchen made an opposing point, noting that Silicon Valley is funded by venture capitalists to do what they want to do. The better approach is going to the original equipment manufacturers (OEMs). Mr. Weiser agreed, but added that there are people who are doing whole systems, and those who are doing components. The thing to consider is that a lot of these people are still intellectually curious and philosophically altruistic. He felt that people can love a mission and work somewhere other than NASA and still want to help. The work doesn't have to be competitive. A partnership can also be a good way to share knowledge among peers to solve difficult problems. NASA still carries a cachet for the best and the brightest. Anything that a company can use as a competitive advantage is helpful, and if they get some acknowledgment from NASA, it's very beneficial to them. Mr. Weiser said he would argue that the bigger players would be less forthcoming than the smaller ones. Mr. Manning noted that he was always pleasantly surprised at the higher nature of people who are interested in contributing to NASA, and of the continuing existence of good citizenship.

Outbrief to the SMD AA

Dr. Wadhwa told Dr. Zurbuchen that the SC was pleased with NASA's efforts in promoting diversity. Dr. Zurbuchen asked the SC to respond by giving an action to NASA to affirm best practices for diversity. He didn't want to wait, and wanted to put out the signal that NASA is very serious about the subject. He asked SC members to bring everything to the table. He personally felt that implicit bias training had been very valuable, and it had made him a more structured thinker. Dr. Shepherd offered to be a conduit for best practices from the American Meteorological Society (AMS), which has gotten very serious about the issue. AMS has just set up a board to collect and develop best practices, and as soon as it is published, Dr. Shepherd said he would share it with NASA. Dr. Cerf felt that visible, swift, decisive action was key, and an important adjunct to training. Dr. Liemohn volunteered to bring best practices from the American Geophysical Union (AGU). Dr. Secada offered to bring some ideas to the fore as well, and asked if bias training actually makes things worse. He noted that no one likes to be called sexist or racist; a better approach is to remove barriers, and to inject nuance when talking about removing bias.

In the area of autonomy, Dr. Zurbuchen thought it would be useful if the SC could drive this to an action item as well. Any exchange that could be facilitated by SC members, to bring together peers to discuss autonomy and find a set of modalities that might lead to mission-changing technologies, would be very valuable. How do we move autonomy partnerships forward, how do we inject more autonomy into flight systems, using the collective wisdom of the science community, as opposed to NASA? What's the how? Dr. Cerf was more interested in infrastructure and enabling technologies, and what gets in the way of the thinking in the science community: What missions are you not doing, what got in the way? How do we uncover this? Mr. Weiser noted that large corporations do these exercises all the time in R&D. It is hard to manufacture serendipity, but there are development frameworks. Step one is to have many awkward conversations to get to the one good one. Make small steps with a representative population, launch a

couple of projects that will attract them. That will start to inform the framework. Dr. Cerf added that when Steve Jobs was redesigning Pixar, he put all the toilets in the middle of the building to encourage interaction. Dr. Zurbuchen asked: how can we take advantage of existing industrial autonomy techniques to build telescopes in space? Or using Europa as an example: how does NASA reach out and ask how it can be done? NASA can't really answer these questions without a focus. Dr. Cerf observed that most big successes come in predictable environments; on the other hand, getting robots to pick up random shaped objects and sort them effectively can be done through machine learning. But it takes a lot of training. The same is true with simulations with self-driving cars; through simulation, one can get billions of miles of experience. Dr. Flanagan commented that the astrophysics community is thinking about robotic servicing, but this has many unintended consequences. Deep-space assembly of large telescopes in space is highly cost-prohibitive. Dr. Zurbuchen encouraged the SC to come back with a finding to help NASA move forward, with defined processes NASA might want to invest in.

Earth Science Interdivisional Activities

Dr. Michael Freilich, Division Director, gave an overview of ESD interdivisional activities. He noted that the Mars Curiosity rover would never have flown without radiation-tolerant flash memory developed by the Earth Science Technology Office (ESTO). Similarly, ESD developed an HgCdTe focal array for mid-wave infrared detection, which was picked up for use in Mars lidar and for a variety of planetary applications. ESD has used astrophysics infrastructure as well as its balloon facility for a number of its projects, and a precision-pointing platform developed by APD. ESD's Earth Surface Mineral Dust Source Investigation (EMIT) on ISS is looking at mineralogy, incipient dust, and the radiation balance on Earth. This investigation is potentially valuable for planetary studies, particularly for Mars.

Earth Science Decadal Survey Implementation

Dr. Freilich addressed ESD's adherence to the last decadal survey, first detailing the two main objectives of ESD, which are to understand Earth as an integrated system, and to turn knowledge into products with societal benefit. ESD itself is broken into four basic elements; Flight, including data systems, makes up about 60% of the Earth Science budget, while R&A, Technology, and Applied Sciences comprise the remaining 40%. The Applied Sciences Office is the flexible bridge between the science effort and the needs of the users. ESD has 1700 grants in R&A at any given time.

NASA's Earth Observing System innovations are focused on pushing the limits on how to design these systems to be both efficient and scientifically useful. ESD uses heterogeneous constellations flown in formation to act as virtual observatories, combining complementary measurements. Semi-homogeneous constellations typically combine measurements for the same variable, e.g., global precipitation data. Homogeneous constellations are generally smaller spacecraft flown at increased temporal frequency. ESD is also making measurements from ISS, which enables operations at a fraction of cost of stand-alone missions. ESD is also exploring the use of NASA science instruments on commercial satellites, learning how to interact with industry.

The 2017 Earth Science Decadal Survey was publicly released in January 2018, supporting the ESD and international program of record, and calling for 20-plus launches throughout the decade. This latest survey prioritizes observations over specific missions to ensure implementation flexibility, emphasizes competition as a cost-control method; explicitly encourages and notes the value of international partnerships; and endorses the existing balances in the ESD portfolio. The survey also seeks to maintain Earth Science Research and Analysis (R&A) at approximately 24% of the budget, with 18% allocated for openly competed R&A and 3% for overhead. The survey calls for cost-capping virtually all missions, and recommends a "continuity measurement strand" as an addition to the existing Venture Class program; identifies five Designated Observables for mandatory acquisition (Aerosols; Clouds, Convection and Precipitation/CCP; Mass Change; Surface Biology and Geology/SBG; Surface Deformation and Change), introduces a new competed Explorer flight line with $350M cost constraints to focus on three observables

to be chosen from among seven explicitly identified science areas, and calls for an Incubator Program to mature specific technologies for important future measurement needs, in preparation for next decadal survey. ESD has been asked to plan to cover Planetary Boundary Layer (PBL), and Surface Topography and Vegetation (ST&V), two important areas that are not adequately supported by current technologies.

ESD has been working hard to keep all the stakeholders involved in the decadal survey planning process through an active web page, monthly calls with the Centers, and quarterly calls with external communities, engaging interagency and international partners. Centers are encouraged to discuss and explore possible observable implementation approaches with international partners. ESD will make final partnership determinations and then formalize the necessary international agreements. The framework for the next survey is to provide candidate measurement approaches, but ESD will not be bound by the candidate approaches. NASA plans to direct Designated Observables (DOs) to NASA Centers. Each mission/observing system will be cost-constrained, with payloads competed out of Headquarters. Satellite buses are expected to be procured. There are no Flagships planned for the next program. SBG or some combination of Aerosols/CCP will be the first DOs mission/observing mission to be initiated. ESD is in a study phase for the DOs, for which it does not have the budget or design at present. The Division is casting a wide net on observing system architectures, and is asking for multi-Center studies. Four multi-Center studies are already under way, funded at several million dollars per year as a baseline. The first study should be ready in late 2020 or early 2021. ESD has been specifically asked to consider non-traditional architectures, and has issued a Request for Information (RFI) to non-federal-government entities, asking them how they'd like to be involved in the studies. NASA is actively exploring how to interact with industry in different ways.

ESD's top-level approach to an Earth Venture Class-Continuity (EV-C) strand is to use it for demonstrating techniques or approaches for long-term observations. The first EV-C mission will be targeted to radiation budget measurements to replace the radiation budget instrument (RBI). ESD is now preparing an EV-C solicitation for release at the end of December, and will do this every 36 months, interleaved with Earth Venture-Instrument solicitations. ESD took a few liberties with the original language for the Incubator concept as described in the decadal survey, taking Atmospheric Winds off the list, and focusing on PBL and ST&V preparations. Strategic decisions on competing the science or the observing systems have yet to be made.

Dr. Wadhwa asked if Dr. Freilich saw any challenges for the next survey, per some ESAC comments. Dr. Freilich felt that the whole distillation process must be done in a way that looks at the entire Earth Science portfolio, while advancing commercial sector partnerships, which constitutes a tremendous management task in addition to the technological task.

Administrator Pop-in

Administrator Bridenstine stepped in briefly to thank everyone on the SC for their service. He mentioned he had just been at the University of Oklahoma, where he had the opportunity to promote the GeoCARB mission at a wonderful event. He introduced the new Deputy Administrator, Mr. Jim Morehard, who brings to NASA his experience in the Senate. Mr. Bridenstine said he was 100% committed to following the guidance of the decadal surveys and keeping NASA out of politics. Mr. Morehard expressed his appreciation for the SC and said he was busy getting his arms around NASA's organizational structure. He cited his background as a legislative appropriator for many years, where he had focused on funding and new opportunities. Committee members introduced themselves to Mr. Morehard.

Findings Discussion

The SC discussed two potential findings, one on the decadal survey and the other on diversity. Ms. Denning took live notes on findings language. The Committee supported the concept of a workshop or Town Hall for advancing next steps in public-private partnerships. Mr. Weiser felt one of the first steps

would be to get the conversations going, and the second step would be the Town Halls. In addition, he thought NASA should create a means to translate between the vernaculars of the participants. Dr. Cerf noted that bringing groups of competitors together could be problematic. Dr. Flanagan said that maybe scientists don't know what capabilities are out there for new missions, or for emerging areas in autonomy. It would be good to know about the latest in x-ray optics, coronagraphy, ultraviolet filters, etc., in public sessions. Mr. Weiser said it was a question of educating the community for the decadal survey versus identifying specific technologies that NASA needs. Dr. Cerf commented that the community knows its aspirations and its instruments, but he argued that scientists are generally less aware of infrastructure. Dr. Larson felt that one should not assume that industry is the only source of innovation, as plenty of innovation is going on at NASA. NASA tends to do the spectacular one-offs, and they are underplayed because they are not mass-produced; there needs to be a balance in the conversation. Perhaps NASA can learn to scale up from industry concepts. Dr. Flanagan said that historically, NASA has done very well by leveraging the dollars in industrial or defense development. Mr. Weiser thought SMD was looking for spin-in for mission-critical items, and because autonomy is receiving a great deal of attention, it could be used as a first example of how to get those conversations started. Dr. Wadhwa suggested that the SC regroup and discuss the topic in more depth. Dr. Larson suggested allowing for more discussion time in future meetings.

In final comments, Dr. Liemohn objected to the use of the word "Explorer" vis à vis new Earth Science Decadal Survey language for a mission strand, calling it a recipe for confusion with the existing NASA Explorers program.

Dr. Wadhwa adjourned the meeting at 2:44 pm.

Appendix A
Meeting Attendees

NAC Science Committee Members
Meenakshi Wadhwa, Arizona State University, ***Interim Chair, Science Committee***
Susan Avery, Woods Hole Oceanographic Institute *(via telecon)*
Vinton Cerf, Google, Inc.
Kathryn Flanagan, Space Telescope Science Institute
Tamara Jernigan, Lawrence Livermore National Laboratory
Michelle Larson, Adler Planetarium
Michael Liemohn, University of Michigan
Feryal Ozel, University of Arizona *(via telecon)*
Pat Patterson, Space Dynamics Laboratory
J. Marshall Shepherd, University of Georgia, Chair, Earth Science Advisory Committee *(via telecon)*
Walter Secada, University of Miami *(via telecon)*
Anne Verbiscer, University of Virginia, Chair, Planetary Science Advisory Committee
Marc Weiser, RPM Ventures
Elaine Denning, NASA Headquarters, ***Executive Secretary, Science Committee***

NASA Attendees
Diane Brown, NASA HQ
T. Jens Feeley, NASA HQ
Michael Freilich, NASA HQ
Ellen Gertsen, NASA HQ
Lori Glaze, NASA HQ
Hashima Hasan, NASA HQ
Michael Henry, NASA HQ
Paul Hertz, NASA HQ
Maudood Khan, NASA ESD
Rob Manning, NASA JPL
Matthew Myers, NASA HQ and GRC
Michael New, NASA HQ
Sarah Noble, NASA HQ
Gregory Robinson, NASA HQ
Delia Santiago-Materese (NASA HQ and ARC)
Michael Seablom, NASA HQ
James Spann, NASA HQ
Eric Smith, NASA HQ
Florence Tan, NASA HQ
Lucia Tsaoussi, NASA HQ
Dan Woods, NASA HQ
Thomas Zurbuchen, SMD AA, NASA HQ

Non-NASA Attendees
Francesco Bordi, Aerospace

Mary Floyd, Zantech IT
Joan Zimmermann, Zantech IT

Telecon/Webex Attendees
Louis Barbier, NASA HQ
Kate Becker, NOAA
DaMara Belson, NASA
James Dean, Florida Today
Ellen Espenschied, NASA
Walt Folkener, Folkener Consulting
Terry Fong, NASA ARC
Jeff Foust, Space News
James Green, NASA
Shobhana Gupta, NASA
Kenneth Hansen, NASA
Grace Hu, Office of Management & Budget
Kim Hurst, NASA
John Karcz, NASA
Jennifer Kearns, NASA HQ SMD
Gib Kirkham, NASA
James Lochner, USRA
Mark Marin, Federal Science Partners
Becky McCauley, NASA
Alfred McEwen, University of AZ
Jeffrey Newmark, NASA
Charles Norton, NASA SMD
Rachel O'Connor, Ball Aerospace
Arik Posner, NASA
Betsy Pugel, NASA
Jonathan Rall, NASA HQ
Christy Rivera, NASA HQ
Michelle Rodrigues, SRI International
John Rummel, SETI Institute
Kartik Sheth, NASA HQ
Marsha Smith, SpacePolicyOnline.com
Thomas Sutliff, NASA
Will Thomas, AIP
Paul Voosen, Science
Meg Urry, Yale University
Nicholas White, USRA

Appendix B
Science Committee Membership

Dr. Meenakshi Wadhwa (Interim 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. Walter G. Secada
University of Miami

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
Presentation Materials

1. NASA Science Overview; *Thomas Zurbuchen*
2. Goals of Fall 2018 Meeting; *Meenakshi Wadhwa*
3. NASA Astrophysics; *Paul Hertz*
4. NASA Planetary Science; *Lori Glaze*
5. NASA Heliophysics Science; *James Spann*
6. JWST Status Briefing to the NAC Science Committee; *Gregory Robinson*
7. Psyche—Journey to a Metal World; *Diane Brown, Sarah Noble*
8. Planetary Science Advisory Committee Report; *Anne Verbiscer*
9. Heliophysics Advisory Committee Report; *Michael Liemohn*
10. Astrophysics Advisory Committee Report; *Feryal Ozel*
11. Earth Science Advisory Committee Report; *J. Marshall Shepherd*
12. Equity and Inclusion in STEM: Where We Are, Why and How to Get to Parity; *Meg Urry*
13. SMD Actions and Research; *Michael New*
14. NASA Autonomous Systems Research and Development; *Terry Fong,*
15. Deep Space Autonomy: A Parochial Perspective from JPL; *Robert Manning*
16. NASA ESD l Survey Implementation Overview; *Michael Freilich*
17. NASA ESD Interdivisional Activity Examples; *Michael Freilich*

Appendix D
Agenda

Dial-In (audio) & WebEx (view presentations online) information is located on page 2.

NASA Advisory Council
Science Committee

November 1-2, 2018

NASA Headquarters
Room 9H40, Program Review Center

Agenda
(Eastern Time)

Thursday, November 1

8:30 – 8:45	Opening Remarks / Introduction of Members	Ms. Elaine Denning Dr. Meenakshi Wadhwa
8:45 – 9:30	NASA Science Overview	Dr. Thomas Zurbuchen
9:30 – 9:40	Goals of the Meeting	Dr. Meenakshi Wadhwa
9:40 – 11:00	Decadal Surveys: Status and Inter-Divisional Approaches	
	Astrophysics Decadal Survey	Dr. Paul Hertz
	Planetary Science Decadal Survey	Dr. Lori Glaze
	Heliophysics Decadal Survey	Dr. James Spann
	Earth Science Decadal Survey	Dr. Michael Freilich
	Discussion	All
11:00 – 11:15	***Break***	
11:15 – 12:15	James Webb Space Telescope Update	Mr. Greg Robinson Dr. Paul Hertz Dr. Eric Smith
12:15 – 2:30	***Lunch (Extended)***	
2:30 – 2:45	Video: *Psyche – Journey to a Metal World*	Ms. Diane Brown Dr. Sarah Noble
2:45 – 3:45	Division Advisory Committee Reports	
	Planetary Science Advisory Committee	Dr. Anne Verbiscer
	Heliophysics Advisory Committee	Dr. Michael Liemohn
	Astrophysics Advisory Committee	Dr. Feryal Ozel
	Earth Science Advisory Committee	Dr. Marshall Shepherd
3:45 – 3:55	***Break***	
3:55 – 4:00	Public Comments	
4:00 – 4:30	Discussion	All

Dial-In (audio) & WebEx (view presentations online) information is located on page 2.

Friday, November 2

8:30 – 8:35	Re-Open Meeting	Ms. Elaine Denning Dr. Meenakshi Wadhwa
8:30 – 9:50	Diverse Teams and Safe Environments	
	Equity and Inclusion in STEM: Where We Are, Why, and How to Get to Parity	Dr. Meg Urry, Yale University
	SMD Actions and Research	Dr. Michael New
	Discussion	All
9:50 – 10:00	*Break*	
10:00 – 11:30	Public-Private Partnerships: Future of Autonomy in NASA Missions	Mr. Michael Seablom
	Autonomy Overview	Dr. Terry Fong, Ames Research Center
	Brief History of Autonomy in Deep Space Missions	Mr. Robert Manning, Jet Propulsion Lab
	Sample Design Reference Mission Wrap-up	Mr. Michael Seablom
	Discussion	All
11:30 – 12:00	Preliminary Outbrief for SMD AA	Dr. Thomas Zurbuchen
12:00 – 1:00	*Lunch*	
1:00 – 2:00	Decadal Surveys: Implementation	
	Earth Science Decadal Survey	Dr. Michael Freilich
	Discussion	All
2:00 – 2:30	Discussion, Findings and Recommendations	All
2:30	*Adjourn*	

Dial-In and WebEx Information

For entire meeting November 1-2, 2018

Dial-In (audio): Dial the USA toll free number 1-888-324-2680 or toll number 1-517-308-9418 and then enter the numeric participant passcode: 8870080. You must use a touch-tone phone to participate in this meeting.

WebEx (view presentations online): The web link is https://nasa.webex.com, the meeting number is 991 102 227, and the password is SC@Nov2018 (case sensitive).

** All times are Eastern Time **