

NASA ADVISORY COUNCIL

SCIENCE COMMITTEE

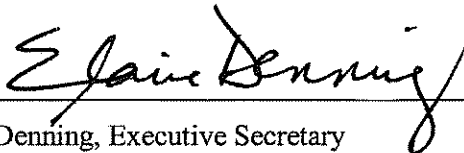
July 25-27, 2016

Ohio Aerospace Institute
Cleveland, OH

MEETING REPORT



Bradley Peterson, Chair



Elaine Denning, Executive Secretary

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July 25-27, 2016

Opening Remarks

Ms. Elaine Denning, Executive Secretary of the Science Committee (SC), opened the meeting and made administrative announcements, enumerated Federal Advisory Committee Act (FACA) rules, and introduced Dr. Bradley Peterson, Chair of the SC. Dr. Peterson asked the SC members to introduce themselves.

Update on Chartering SMD Division Committees

Ms. Denning provided details of a NASA proposal to make the four SC subcommittees standalone FACA committees, to advise each Science Mission Directorate (SMD) division. NASA believes this chartering will enhance reporting and study engagement, as well as continuity and flow within the current system. The change is a minor operational one; there are now terms of reference (TOR) and a process is in place for putting together charters and membership balance plans to ensure proper spans of expertise. These documents will then be reviewed by the General Services Administration, announced in the Federal Register, and filed with Congress. This transition had been discussed by NASA Administrator Charles Bolden and former NAC Chair Dr. Steve Squyres in the Spring, and the drafts are now in the clearance process. The timeline for final disposition is still to be determined. As an example, the Astrophysics Subcommittee (APS) will become the Astrophysics Advisory Committee (APAC), and will report to Dr. Paul Hertz, Director of the Astrophysics Division. Dr. Scott Gaudi, Chair of the APS (APAC) will continue to serve on the SC. Once the APAC is chartered, Dr. Hertz will establish Senior Reviews, science and technical definition teams (STDTs), etc., under the new auspices of APAC. Dr. Mark Robinson asked about the role of the SC given these changes. Ms. Denning noted that the SC will continue to be the right place to bring major or cross-cutting SMD matters and to share best practices, and it has the perspectives of several at-large members (e.g. human spaceflight, STEM education). Dr. Peterson expressed the wish for committee chairs to provide findings and recommendations to the division directors and also to the SC for feedback. He noted also that newly appointed SMD Acting Associate Administrator, Mr. Geoff Yoder, is now looking at SMD from a more integrated point of view, seeking commonalities among the divisions; this will be a topic of further discussion. Dr. Robert Lindberg, Chair of the Planetary Protection Subcommittee, noted that PPS has seemingly been left out of the discussion, and that furthermore, PPS had been demoted from advisory committee status six years earlier. He felt it might be time to consider realignment of the advisory function of PPS, as it has increasing relevance to human exploration. PPS has also recommended that the Planetary Protection Office (PPO) be aligned separately from the SMD, and perhaps this thought should also be applied to the PPS. Dr. Peterson agreed to bring up the issue at the NAC level.

Dr. Peterson introduced Mr. Kenneth Bowersox, Interim Chair for the NASA Advisory Council (NAC), who described the transition as a very dynamic time, adding a request that the Science Committee formulate a list of observations and concerns for the Administrator, and potentially, for future transition teams. Mr. Bowersox sat in during the early part of the meeting.

Juno Orbit Insertion

Dr. James Green, Director of the Planetary Science Division (PSD) reported first on the July 4 insertion of the Juno spacecraft at Jupiter. The Juno mission has four science objectives: to understand the origin, interior structure, atmospheric composition and dynamics, and polar magnetosphere of the planet. Juno is powered by large (66-foot diameter) solar arrays, and carries nine instruments, including high-definition visible cameras (Juno Cam), an infrared (IR) camera contributed by the Italians, and a microwave radiometer. Juno Cam will deliver full-color images as part of an education and outreach effort; images will be posted immediately to the Juno Cam website, where there is also an opportunity for amateurs to post images contemporaneously. The first set of visible images is due later in August. The IR instrument, the Jovian Infrared Auroral Mapper (JIRAM), will obtain high-resolution images of Jupiter's atmosphere and auroral displays in the 2-5 μ m range. Three instruments will be used to study the origins and interior: Gravity Science, Microwave Radiometer, and Magnetometer. The Microwave Radiometer will enable detection of direct microwave signatures to be obtained by taking advantage of orbital features, getting below the obscuring radiation belts. The features of the radiation belts themselves, as well, will be revealed by JIRAM. The instrumentation can sense the deep atmosphere and determine the presence of water and ammonia, and their depths in the upper layers, 500-600 km below the cloudtops. Jupiter's magnetosphere has 20 times the intensity of Earth's. Close, high-precision observations will give an indication of the types of magnetic field currents present. The mission also hopes to see the solar wind interact with Jupiter's aurora, watching it evolve and change in both the southern and northern hemisphere, and learning how they are connected. To understand the polar magnetosphere, Juno will pass directly through auroral field lines. A plasma wave emitter will be able to see Jupiter's radio emissions. Observations will be combined with those of the JAXA satellite Hisaki (extreme ultraviolet spectroscopy) and the Hubble Space Telescope (HST), to provide broader context to Juno observations. Asked by Dr. Gaudi if the mission might determine the existence of a core (via higher order J values), Dr. Green confirmed the mission would measure "J4."

Juno will do one more burn in November to start 14-day orbits, which will provide outstanding coverage of all the planet's longitudes. Cassini will be doing similar coverage of Saturn as it reaches the end of its mission, and will do another flyby of Titan in April 2017 to pass between the planet cloudtops and the F ring. Cassini will perform 22 orbits in the same way as Juno, giving NASA the opportunity to do a giant planet comparison. Dr. Robinson asked why Juno Cam had been turned off on approach, and what the four support cameras were for. Dr. Green noted that the support cameras are star trackers, and help to deconvolve the magnetic field from the spinning spacecraft. These cameras alone may find new moons, in addition to their use in calibrating magnetometer data. Juno Cam was turned off on approach in order to have full power to maneuver the spacecraft. Dr. Peterson asked if there were a reason the reduction burn wouldn't start until November. Dr. Green said he didn't know but could find out.

Planetary Science Division Update

Dr. Green presented a status of the division. Current missions in progress and in development include Mars Interior Exploration using Seismic Investigations Geodesy and Heat Transport (InSight) 2018, the European Space Agency (ESA) ExoMars 2020 mission, and the NASA Mars 2020 rover. The ExoMars Trace Gas Orbiter mission will be in orbit at Mars by October 2016. The ESA Rosetta spacecraft will land on comet 67P Churyumov-Gerasimenko in September 2016, when the mission will come to an end. Juno

will enter its end of mission phase 18-20 months from now. Cassini will impact into Saturn in September 2017. Dawn has enough fuel to stay at Ceres for 8 more months. NASA celebrated the 40th anniversary of Viking this year, a tremendous milestone. Plans for the preparation for Cassini's mission termination will take place in April 2017.

The Discovery program can boast many successes, including the completed MESSENGER mission to Mercury. The Lunar Reconnaissance Orbiter (LRO) still is doing well. NASA's Strofio instrument was delivered to Italy, in preparation for the BepiColombo launch in 2017. InSight is in storage for an anticipated launch in May 2018. PSD has selected five Phase A studies: Psyche, VERITAS, DaVinci, Lucy (Trojan asteroid survey), and NEOCAM, with a downselect to be announced in December 2016. In New Frontiers, which includes Juno and New Horizons mission, we are looking forward to the launch of the Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer (OSIRIS-REx) to a carbonaceous chondrite asteroid, where it will perhaps obtain some organics, and gather data that can further the understanding of the Yarkovsky effect. OSIRIS-REx will arrive at the asteroid Bennu in September 2018, where it will stay for several years, and then return up to a kilogram of sample in 2022. For the upcoming New Frontiers Announcement of Opportunity (AO), PSD alerted the community in January and April, and is considering proposals for Enceladus, a lunar South Pole sample return, and a Venus in-situ explorer, among other missions. The draft is in signature cycle and is expected to be released this summer, with the final AO in January 2017. The launch readiness dates for this latter AO are in 2024.

In the Mars program, ESA is developing a demonstration descent module, Schiaparelli, in preparation for the ExoMars rover. The United Arab Emirates (UAE) has plans for a Mars mission called Hope; NASA has an agreement in several areas with the UAE for a 2020 launch. There is also a plan in the works for a Chinese lander and rover in 2020, with which NASA has no ties. NASA's Europa mission in development is a multi-flyby mission from a Jovian orbit, which will look at Europa as comprehensively as possible. Europa lander studies have also been initiated; a Science Definition Team (SDT) is at work on this currently. CubeSat mission planning include a lunar polar hydrogen mapper, and a CubeSat Particle Aggregation and Collision experiment. Three Simplex CubeSats have been approved for technology development study: a Mars Micro Orbiter, a Hydrogen Albedo Lunar Orbiter, and a Diminutive Asteroid Visitor using Ion Drive (DAVID).

PSD held a Senior Review of nine missions, all of which were approved for extension, including the Mars Reconnaissance Orbiter, Dawn, and New Horizons. New Horizons is scheduled to visit a Kuiper Belt Object (KBO) on January 1, 2019. Final decisions on the extended mission roster will be dependent on the disposition of the budget. The National Academies of Science, Engineering, and Medicine (National Academies) is performing a study on the PSD Research and Analysis (R&A) restructuring, and PSD is asking that a National Academies midterm review be tasked by September 2016. The third planetary Decadal Survey is due to be tasked before October 2019. Dr. Gaudi commented that the Astrophysics Division (APD) is studying four large concepts for input into its Decadal Survey, and asked if PSD was doing anything similar. Dr. Green reported that PSD has created a SDT for Neptune and Uranus (reporting in September 2016), based in part on a mission-enabling asset in the Space Launch System, which would allow direct access to the Outer Planets (OP), making it possible to launch two OP missions

in one decade. Dr. Robinson asked Dr. Green to comment on a Space News article citing cost overruns on Mars 2020. Dr. Green said Mars 2020 (M2020) is not over budget. Recently released numbers merely indicated the lifecycle cost of mission, which includes contributions by Human Exploration (HEOMD), the Space Technology Mission Directorate (STMD), and the cost of the rocket. Previous announcements clearly stated only the SMD cost. Dr. Green reported being quite happy with the progress of Mars 2020, with no overrun to report. Dr. Robinson commented that in December 2012 in proceedings of the American Geophysical Union (AGU), it was stated that the launch costs were part of the \$1.5 billion M2020 figure. Dr. Green found that number hard to believe, given the difficulty of forecasting launch cost that far ahead. Dr. Neal asked if there were any cost changes associated with InSight. Dr. Green reported working with the Centre national d'études spatiales (CNES) to match schedules and other details, and that a total cost analysis was still in progress. Given the delay, it is inevitable that costs will increase. Dr. Green promised to update the PSS at the end of September. Dr. Carlé Pieters asked if any additional Flagship-size missions were being considered, and if Mars Sample Return (MSR) was falling off the chart. Dr. Green replied that NASA is moving forward with MSR, with Mars 2020 (M2020) coring samples for potential return. PSD continues to work with HEOMD and others to determine the way forward. In 6-9 months, there will be a clearer picture of stepwise progression to sample return. Dr. Robinson asked for details on the potential helicopter demonstration on M2020. Dr. Green described the vehicle as a technology demonstration that is being considered for inclusion on M2020 on a "noninterference basis;" it must demonstrate milestones over the next year or it will not be on the mission. Dr. Green felt guardedly optimistic, but allowed that the demonstration still had a way to go.

Planetary Science Subcommittee Report

Dr. Clive Neal, representing the Planetary Science Subcommittee (PSS), presented a briefing on the results of the June 2016 telecon meeting, reporting that membership is changing, with rotations both off and on the subcommittee. These changes are pending confirmation due to the restructuring, but Dr. Neal felt that PSS remains representative of the community. The abbreviated meeting agenda resulted in two findings, the first regarding transparency of communications in the Mars program regarding MSR and other developments. The PSS is concerned about the transparency of progress to the community and wanted to establish better feedback, as well as better communication about science opportunities. Dr. Neal also noted that PSS needs more direct communication with PPS, dedicated time to talk about issues relevant to both groups, particularly with respect to planetary protection implications surrounding Mars and Europa. Dr. Lindberg agreed that there were some asynchrony challenges to be overcome. Dr. Neal recommended that the SC create a finding to support a united front between PPS and PSS, and Dr. Peterson agreed. Dr. Lindberg felt that Ms. Denning's proactive involvement with the two Executive Secretaries would be helpful to the cause.

PSS issued a second finding on the diminishing ability of PI-led laboratories to maintain state-of-the-art analytical facilities, a situation worrisome for the increasing number of sample returns in the future mission roster. A recent survey conducted by PSS confirms that this concern is valid, and also provides evidence that implies fewer training opportunities for the next generation of technicians. The recent PSD R&A re-organization has contributed to the problem, thus researchers need new and creative ways to support these laboratories, possibly necessitating creation of a task force to suggest solutions.

Dr. Neal presented other meeting observations. While PSS had harbored previous concerns about the inclusion of Ocean Worlds in the New Frontiers program, it has since concluded that Ocean Worlds does not change science priorities as laid out in the Decadal Survey. PSD's recent funding for the COLDTech instrument development opportunity bears out this conclusion. A National Academies report on SMD's Senior Review process is due out soon. Planned exploration of "special regions" at Mars and instrument development for exploration of OP moons such as Europa will soon necessitate a joint meeting of PSS and PPS. Regarding community-reported problems with the Deep Space Network (DSN), Dr. Neal thanked the SC for obtaining a response to the SC and PSS finding on the matter, but said the PSS still harbored questions about what some of the DSN statistics meant. He felt it hard to believe the presented metrics were inclusive, and requested some clarification. Dr. Peterson agreed that the Committee couldn't tolerate NASA putting a happy face on the DSN issue.

Planetary highlights include evidence of active, present-day volcanism on Venus, as captured by Venus Express imagery of Themis Regio, clearly demonstrating melting and eruptions on the surface of Venus. An unexpected discovery of tridymite, silicon that is volcanic in origin, was made in Mars mudstone by the Curiosity rover. An analysis of the Imbrium Sculpture on the lunar near side suggests that the causative impactor was a proto-planet half the size of Vesta. The Cassini Grand Finale was highlighted in an issue of Nature Geoscience (July 2016). The next PSS meeting will take place in September at NASA Headquarters.

Planetary Defense Coordination Office

Mr. Lindley Johnson, Program Executive for the Planetary Defense Coordination Office (PDCO), provided a briefing on the progress of implementing defense against the asteroid impact hazard. The Chelyabinsk, Russia event in February 2013, the largest and most documented event in recent decades, caused tens of millions of dollars of damage, and over 1600 injuries. National interest in asteroid hazards was naturally raised at that time, but NASA tasking had already been laid out in the 2010 National Space Policy. An October 2010 OSTP letter to Congress marked NASA's responsibility for discovering and tracking potentially hazardous near-Earth objects (NEOs), and constitutes the current guidance for NASA. The PDCO was established to work efforts across NASA mission directorates and centers, and across government agencies and international bodies. NASA is leading national and international efforts for planetary defense.

PDCO reports to the PSD Program Director, through to the SMD Associate Administrator (SMD AA). Most of the funding implemented in the NEO Observation Program has been formalized as a research program, led by a Program Manager and Program Scientist. PDCO also works with emergency response organizations (e.g., FEMA) in tabletop exercises to develop emergency response plans, as well as mitigation response plans for asteroid orbit deflection, including the Asteroid Redirect Mission (ARM) with HEOMD and STMD, and the Asteroid Impact Deflection Assessment (AIDA) mission with ESA.

The NEO Observation Program detects and tracks bodies that approach within 28 million miles of Earth's orbit, and has provided 98% of new detections since 1998. In terms of known Near Earth asteroids, as of July 25, the program has identified 14,560 objects. Potentially hazardous objects are defined as being within 5 million miles of Earth's orbit. Within the current catalogue, there are 1707 potentially hazardous

asteroids (PHAs), with 157 being larger than 1 kilometer in size, but none known are projected to have a significant probability of impact within 100 years. NASA has yet to reach its goal of completing the detection of at least 90% of the population of 140m+ objects, but Mr. Johnson noted that the search is about 93% complete for 1km+ objects. He pointed out that an impact by a half-kilometer asteroid could have continent-wide effects. To date, NASA hasn't detected any objects with potential for civilization-ending impacts. Current survey facilities being used to detect NEOs include the Pan-STARRS telescope (Haleakala, HI), LINEAR/SST (MIT/LL), Catalina Sky Survey (University of Arizona), and NEO-WISE, the warm-phase extension of the Wide-Field Infrared Survey Explorer (WISE). The program reports out detections and orbit analysis through the Minor Planet Center, and the Center for NEO Studies at the Jet Propulsion Laboratory (JPL) and operates as part of the International Asteroid Warning Network. As more capable telescopes are added to the program, discoveries will include more 140m+ NEOs, and NASA may get close to 2000 new discoveries of all sized objects this year. Discoveries of 140m+ objects now constitutes about a third of the total discoveries each year. If the population is 25-26,000, then there are still about 74%, or 18,000 of this size and larger objects to be found.

The asteroid designated 2016 HO3, a quasi-moon for Earth, is being tracked as a potential target for a CubeSat mission. Primary enhancements are being made at the Goldstone and Arecibo radar facilities, the NASA Infrared Telescope Facility (IRTF) at Mauna Kea, and for the Spitzer warm-operations mission. As an example of recent activities, an object found in February was used to test rapid response-observing protocols and coordination for fast moving objects. Arecibo observed in October 2015, the "Great Pumpkin" asteroid flyby, which was also characterized by the IRTF. It was concluded that the object was most likely a dead comet nucleus, and NASA obtained good resolution using a number of facilities (radar, IR, and visible). Mr. Johnson displayed a chart on bolide events, which showed locations of impacts from objects ranging from 1m to 20m in size during the period 1994-2013. This data is available at <http://neo.jpl.nasa.gov/fireballs/>.

PDCO is also working on an Asteroid Threat Assessment Project (ATAP), along with FEMA with which it holds joint Impact Emergency Response Exercises. There will be another exercise with FEMA this Fall. NASA also works with the UN's Committee on the Peaceful Uses of Outer Space (COPUOS)/Office for Outer Space Affairs (OOSA) on international plans for impact threat response. The UN has endorsed the International Asteroid Warning Network, and also the Space Missions Planning Advisory Group (SMPAG) for planning in-space mitigation response capabilities. PDCO is looking at options for in-space deflection, including nuclear, kinetic (most mature and viable), and gravity tractor (a SEP mission could demonstrate this technology), and is working with the DOE on response for short-term warning events. ESA is developing an Asteroid Impact & Deflection Assessment (AIDA) mission concept jointly with NASA, currently in parallel formulation studies, whose target is to characterize Didymos, a binary near-Earth asteroid, and demonstrate kinetic deflection techniques. PDCO is working to identify candidate targets for the ARM, as well as assist with its Planetary Defense Demo (a gravity tractor demonstration with the ARM robotic mission).

Dr. Peterson asked if anyone had considered broadening the PDCO charge to covering other hazards, such as coronal mass ejections (CMEs). Mr. Johnson replied that there is another community working this issue, through a two-year-old space weather strategy and action plan. Dr. Susan Avery asked if NASA

was working on quantifying the risk of the hazards, in addition to characterization. Mr. Johnson reported that ATAP is doing this risk assessment, and is looking at detailed modeling of impact effects based on the size and composition of the objects. Probability-of-impact modeling is being done at JPL, based on the best knowledge of orbits. Dr. Gaudi asked about non-gravitational effects on NEOs. Mr. Johnson indicated that these effects are being modeled as well. The OSIRIS-REx mission will investigate the Yarkovsky effect (minute thrust from the absorption and re-radiation of heat from the Sun). Mr. Johnson agreed that heating and venting of volatiles on these objects may play a significant, if not yet well-understood, role in perturbing their orbits.

Planetary Protection Subcommittee Report

Dr. Lindberg presented results from the most recent PPS meeting, which included updates from SMD, the Mars Exploration Program (MEP) and the PPO, and a focus on microbiology. There was much discussion about planetary protection implications for commercial missions, entailing some discussions for which Dr. Lindberg was compelled to recuse himself. A M2020 update prompted a significant discussion on the planetary protection approach to the sample collection system. Requirements for sample returns will require protection against microbial contamination, and approaches include whole spacecraft sterilization (Viking-era) vs. subsystem sterilization (Phoenix). There was considerable discussion about what constitutes a subsystem. PPS finds M2020 to be using an unusual approach (i.e. keeping only the interior of sample tube clean). There were also planetary protection issues associated with the proposed M2020 helicopter demonstration.

PPS heard a science briefing on biofilm prevention techniques that may have relevance for planetary protection on spacecraft, and also heard a programmatic view of investment planning at STMD, noting again that there is a worrisome lack of investment in planetary protection technology. PPS fears it has been unable to get STMD to embrace planetary protection technologies that will enable NASA to go to water worlds or Mars, or to send humans to Mars. PPS issued a recommendation that NASA assign an additional full-time equivalent (FTE) civil servant to the PPO, reasoning that a one-person office at Headquarters is inadequate given the growing number of missions that have planetary protection consequences. PPS notes that there is an increasing load on PPO that is not accompanied by concomitant funding.

A recommendation which prompted Dr. Lindberg's recusal at the PPS meeting was a call for action on commercial launches, as NASA's interest is in preventing forward contamination. The PPS reports this without opinion. Dr. Lindberg said he would recuse himself again when SC undertakes its discussion. The PPO concern reflected in this recommendation is to protect Solar System bodies in an effort to protect the science integrity of future missions. Dr. Peterson felt this may be more of a scientific integrity issue, thus making it a mission responsibility, and not that of the PPO. Dr. Lindberg thought the issue with M2020 was both a question of scientific integrity, and the planetary protection injunction to protect science from both biological and chemical contamination, which could not be separated. Dr. Neal agreed with this assessment. Dr. Peterson agreed to take the recommendation to further consideration.

The PPS made an observation, welcoming NASA's attention to investment in planetary protection technologies, and the creation of a Planetary Protection Technology Definition Team (PPTDT) to identify

processes and catalogue techniques for planetary protection. The PPS felt this to be a good move, and in part a response to SC concerns. Dr. Peterson said that Administrator Bolden had concurred with the recent SC recommendation on this matter. Dr. Lindberg briefly reviewed some open recommendations from previous meetings, including one that supports the adoption of the 2015 Bern COSPAR workshop findings on Mars special regions.

Joint Agency Satellite Division

Ms. Sandra Smalley, the newly-appointed Director of the Joint Agency Satellite Division (JASD), presented an update, acknowledging new Deputy Director John Lee, Michelle Calloway, and a new Integration Program Executive, Peter Wilczynski, who is on detail from the National Oceanic and Atmospheric Administration (NOAA), and the Program Executive for the Joint Polar Satellite System (JPSS).

Ms. Smalley reviewed JASD's reimbursable launch commitment dates and near-term milestone schedule. Currently NASA is transitioning from the Advanced Composition Explorer (ACE) satellite to the Deep Space Climate Observatory (DSCOVR) for operational space weather (SW) forecasting. DSCOVR is the first operational SW satellite at Lagrange Point-1 (L-1), where it continues solar wind measurements, and observes the Earth from unique Sun-Earth L-1 point. DSCOVR instruments include a Faraday cup, fluxgate magnetometer, an Earth Polychromatic Imaging Camera (EPIC), National Institute of Standards and Technology Advanced Radiometer (NISTAR), and Electron Spectrometer and Pulsed Height Analyzer (PHA). The spacecraft arrived at L-1 in June 2015, and since that time, EPIC has been providing 22 images of Earth per day. DSCOVR will start transmitting data currently provided by ACE and will become a NOAA operational asset on July 27.

The Jason-3 satellite provides measurements of the global sea surface height to an accuracy of 4 cm every 10 days, monitors phenomena such as ocean circulation, and will extend the time series measurements of ocean topography, global sea level rise, ocean heat content, and other parameters. Jason-3 carries five instruments: an altimeter, Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS), GPS payload, Advanced Microwave Radiometer, and a Laser Retroreflector Array (LRA). Jason-3 launched on January 17, 2016. All instruments were activated as of January 20. Jason-3 reached its final planned orbit in February, when it was handed over to NOAA, where it is operating nominally.

Geostationary Operational Environmental Satellite (GOES-R) is the next generation of the geostationary weather satellite system, designed to provide continuous imagery and to contribute to SW predictions. GOES-R carries six instruments: Advanced Baseline Imager (ABI), Geostationary Lightning Mapper (GLM), Space Environment In-Situ Suite (SEISS), magnetometer, Solar Ultraviolet Imager (SUVI), and Extreme Ultraviolet and X-ray Irradiance Sensors (EXIS). GOES-R will launch on November 4, 2016, and GOES-S is in preparation to launch in the fourth quarter of FY2018. GOES-T and U are under contract, and have had some manufacturing readiness reviews.

The Joint Polar Satellite System (JPSS) is the next generation of polar-orbiting environmental satellites, providing continuity for global environmental data used in numerical weather prediction models and climate modeling. Instruments aboard this series of satellites will measure components of the Earth

radiation budget, and provide data on atmospheric temperature/moisture profiles, hurricane intensity and position, tornado potential of thunderstorms, Alaska “nowcasting” (e.g., ice detection), significant precipitation and floods, dense fog, volcanic ash, fire and smoke, sea surface temperature, ocean color, sea ice extent and snow cover, vegetation greenness indices and health, oil spills, and derived winds (speed/direction/height).

JPSS-1 is undergoing a series of reviews and is scheduled for launch in the second quarter of FY2017 from Vandenberg Air Force Base on a Delta II rocket, and JPSS-2/3/4 are in progress, with a spacecraft bus having been awarded to Orbital ATK in March 2015, including options for 3 and 4. The division is working hard to avoid gaps in data.

The MetOp-C project will measure the temperature and humidity profile of Earth’s atmosphere, and carries four instruments, with a mission life of five years. Thermal vacuum testing is due to be carried out on this satellite in April 2017.

In summary, NASA and NOAA are continuing a productive partnership, and NASA is working several Interagency Agreements: a Future Architecture Study for the next generation of space weather satellite systems, a study for the space weather follow-on to DSCOVR, a study for a COSMIC-2B (Constellation Observing System for Meteorology, Ionosphere, and Climate-2B) rideshare opportunity on the NASA SWOT (Surface Water & Ocean Topography) mission, an agreement to support the transition of the JPSS Enterprise Ground System, and a study with JPL to advance the technology of the EON-IR (Earth Observing Nanosatellite Infrared) instrument.

Dr. Lindberg commented on JASD’s significant workload and asked if the office were adequately staffed. Ms. Smalley replied in the affirmative, explaining that its two teams are cognizant of stress levels, and are working to prevent burnout. Dr. Robinson asked about the program costs, and if the follow-ons were “build to print.” Ms. Smalley indicated that the follow-ons were indeed build-to-print. The total program cost of GOES-R is \$10B, and JPSS is about the same order of magnitude.

Harmful Algal Blooms

Dr. John Lekki, NASA Glenn Research Center (GRC), briefed the SC on the Earth Science Division’s (ESD) airborne monitoring program of harmful algal blooms (HABs) in the Great Lakes region. HABs are natural phenomena that are presenting serious problems in both health and recreational terms, nationwide. NASA ESD is involved with a number of interagency efforts in monitoring and forecasting these algal blooms. There are growing issues with water quality in Lake Erie, and a potential for toxins entering the Toledo water system. There are also water taste issues, and widespread fish kills that are having impacts on both recreational activities and commercial catches. The 2015 bloom in western Lake Erie was the most severe to be seen in this century. Notably, the Ohio River had a 500-mile HAB in 2015. Reduction of phosphorus runoff had ameliorated the issue temporarily, but in 1995, the problem resurfaced. ESD began using hyperspectral imagery to monitor HABs in fresh water, with an aim to differentiate HABs from nuisance blooms. To do this, ESD is using Moderate Resolution Imaging Spectroradiometer (MODIS)-Terra satellite imagery compared with hyperspectral imaging, and is also coordinating with the Ohio Environmental Protection Agency HAB coordinator.

In 2006, NASA developed a first-generation miniature hyperspectral imager. This year NASA is planning 26 flights, and is developing *Microcystis* (hepato- and neurotoxic cyanobacteria) indication maps with research partners including NOAA, University of Toledo, Kent State University, Michigan Tech, University of Cincinnati, and the Naval Research Laboratory. Using lessons learned from 2014, the project has developed better atmospheric correction techniques and has begun to turn around data reporting more quickly. A typical “quicklook” involves getting imagery from the satellite to get an indication of where blooms are an issue, georeferencing the data, then flying over and taking spectra with the hyperspectral imager (HSI). The imager can see under clouds and in the rain.

The project is continuing to refine atmospheric correction, and has tested several models. The best correction is done by using empirical line correction (using a sequestered parking lot as a reference). There is also a ground-based radiometer system, and mirror arrays to improve the quality of atmospheric corrections.

Dr. Joseph Ortiz briefed the SC on the use of visible and near-infrared (NIR) derivative spectroscopy to separate the contribution of cyanobacteria, algae, suspended sediment and colored dissolved organic matter from the total spectrum. After obtaining spectral derivative signatures of different lakes, resulting in distinct spectral shapes, vari-max rotated, principal component analysis (VPCA) is used to differentiate the algal classes. A direct comparison of different sources of spectral reflectance is used to obtain the signatures. Dr. Neal asked if footprints were compared as well, and asked about method sensitivity. Dr. Ortiz explained that data from the ground made over several weeks provides a dataset that gives enough variability to separate out the toxic signal from the nontoxic signal. VPCA is applied to MODIS data on a relatively regular basis, and the method can also be applied to lab samples, field-based radiometers, and remote-sensing data. The data are being archived at the Ohio Supercomputing Center.

Dr. Robert Schuchman briefed on improved Cyanobacteria Index (CI) detection using hyperspectral reflectance, noting first that the collaborations between NASA, NOAA, the U.S. Geological Service (USGS), and the Environmental Protection Agency (EPA) have been fantastic, and the leveraging of *in situ* observations with remote sensing has enabled tremendous progress to date. This effort could easily be repeated for other applications with a remote-sensing element. Conventional algorithms are limited, however; NASA HSI hyperspectral data can be tailored to better match spectral shapes, and new algorithms can be developed that are better suited to blue-green algae detection instead of more general high chlorophyll detection. There is poor CI discrimination in green/diatom-dominated waters. Spectra from pure blue-green algae (high absorbance in 620-640 nm range) are much different from that of a high chlorophyll concentration. The project is working on improved algorithms, and is now applying machine-learning algorithms to hyperspectral data sets from 2015. Results indicate that it is possible to classify dominant algal groups with about 70% accuracy. Classifying whether spectra was blue-green-dominated or not was done with 92% accuracy. The next steps are to evaluate blue-green algorithms using field data, continue testing with a robust data set, and continue a time-series analysis of near-continuous radiometric monitoring of two sites: a parking lot and a lighthouse in the middle of Lake Erie.

Dr. Lekki noted the development of new platforms, using early career teams, to integrate a HSI into an Unmanned Aerial Vehicle (UAV) starting in August 2016, flying over Lake Erie. GRC is building two

HSIs appropriate for a CubeSat as well as new algorithms. Benefits will include improved monitoring, data provision for a number of missions and which complements existing satellite data; and methods of producing operational HSI data products.

Dr. Robinson asked how the effort could be used to support prevention. Dr. Lekki said the program already has the attention of Congress, and there are plans underway to reduce phosphorus outflow by 40%. Recently in the region, application of fertilizer to frozen surfaces has been prohibited. Dr. Avery commented that forecasting will take more than algorithms and asked if the HSI project was interfacing with this community. Dr. Schuchman reported that there is a user working group headed by the science center in Ann Arbor, MI, which is working on forecast models to determine cause and effect as far as possible. The other player is EPA, which is working to reduce sediment and nutrient loads, in part based on remote-sensing data.

July 26, 2016

Ms. Denning opened the meeting and turned over meeting to Dr. Peterson. Dr. Peterson welcomed new SC member Dr. Tamara Jernigan and Mr. Geoff Yoder, Acting AA for SMD.

Astrophysics Division Update

Ms. Andrea Razzaghi, Deputy Director of the Astrophysics Division (APD), provided a briefing on the status of the division. APD has a \$1.35 billion budget for FY16, including funds for completion and launch of the James Webb Space Telescope (JWST) and the beginning of the Wide-Field Infrared Survey Telescope (WFIRST). Operating missions are doing well. The Stratospheric Observatory for Infrared Astronomy (SOFIA) is in its five-year prime operations as of May 2014. Five Small Explorer (SMEX) and Mission of Opportunity (MoO) concept studies were selected in 2015. APD has been able to maintain a robust R&A budget, however it has had a two-fold increase in proposals, which is putting pressure on selection rates. Draft solicitations are in process for a mid-Explorer (MIDEX) AO released on July 14. MIDEX has a cost cap of \$250M. The current portfolio includes several missions extended by the 2016 Senior Review: HST, Chandra, Fermi, Kepler/K2, NuStar, Spitzer, Swift and the NASA component of ESA's X-ray Multi-Mirror Mission (XMM). Spitzer will come to the end of its mission in mid-FY19.

APD just completed its 2016 New Zealand superpressure balloon (SPB) campaign, for a total of 46 days aloft, landing on July 2. The test flight carried a science MoO, the Compton Spectrometer and Imager (COSI) payload. The balloon and payload were recovered in Peru. The ST7 LISA Pathfinder launched in December 2015, and had an anomaly that delayed science operations for a month, which has since been solved with a workaround. The Japanese Space Agency's (JAXA) Hitomi soft x-ray telescope, launched on February 2017, suffered a mission-ending spacecraft anomaly on March 28. Prior to failure, the NASA-JAXA-built soft x-ray spectrometer (SXS) demonstrated that it exceeded requirements. JAXA will pursue a replacement mission, and NASA is interested in partnering with the new mission to build a new SXS.

Astrophysics missions in development include the Neutron star Interior Composition Explorer (NICER), Cosmic Ray Energetics And Mass (CREAM), Transiting Exoplanet Survey Satellite (TESS), JWST, Euclid and WFIRST. NICER is a MoO on the International Space Station (ISS), to be launched in

February 2017 on the SpaceX-11 flight. TESS is progressing well to a December 2017 launch readiness date from Cape Canaveral. JWST continues to make progress; its mirrors have been installed and instruments integrated. The second test of the LISA Pathfinder telescope and ground support equipment was carried out at Johnson Space Center (JSC); plans for 2016 include the installation of the sunshield, which is undergoing thermal balance testing. WFIRST completed a mission concept review (MCR), has selected members of its Formulation Science Investigation Teams, and has selected Ball and Lockheed-Martin to support wide-field instrument studies. WFIRST is on track to reach Technology Readiness Level (TRL) 6 for some critical instruments by next year (launch scheduled in mid-2020s).

FY17 appropriations for APD are subject to Senate and House markups, and will likely have some directed funding. The division expects to be able to manage any resulting funding challenges. Currently, APD is studying four large mission concepts in preparation for the 2020 Decadal Survey (Far IR Surveyor, Habitable-Exoplanet Imaging Mission, Large UV/Optical/IR Surveyor, and X-ray Surveyor) and looking at technology gaps. APD plans to issue a call for medium-sized mission studies (“probes”) as well.

Astrophysics Subcommittee Report

Dr. Scott Gaudi, Astrophysics Subcommittee (APS) Chair, reported on its latest meeting, briefly reviewing membership, which includes the chairs of the science teams for the previously mentioned large-mission concept studies. He presented some science results from K2, which looks at the ecliptic plane, monitoring galaxies for the shock breakout (bright flash of light) of supernovae. K2 has enabled us to see this in visible wavelengths. Before Hitomi failed, its SXS was pointed to the Perseus cluster and was able to resolve velocities in its gas clouds, a striking demonstration of Hitomi’s potential power. Among other notable science results was a refinement of the Hubble constant using measurements of the distance of Cepheid stars in the Milky Way, and a Spitzer follow-up of a star hosting four known planets. Spitzer detected the transits of one of the planets with a mass of 4.5 times the mass of the Earth. This is the closest transiting system to Earth and will be a great target for JWST. An HST result on the dwarf planet Makemake in the Kuiper Belt indicated that it has a moon likely formed from a collision. The orbit of the moon is almost edge-on, accounting for it not having been observed previously.

The APS held its meeting a week prior at NASA Headquarters, and heard about the restructuring of the four science subcommittees, and the possible restructuring of the Fellows program. APS intends to provide a recommendation on the latter subject in October. APS is also considering a possible restructuring of the Roman Technology Fellowship, to reduce overhead on the selection process, but hasn’t reached a conclusion yet. The subcommittee heard noncontroversial reports from the analysis groups (AGs), JWST and WFIRST.

A charge has been made to the PAGs on Astrophysics Probes (\$400M to \$1B), after which APD will solicit competitive mission concept studies, with proposals to be selected on science merit and NASA objectives, and a realistic cost assessment. Total funding for the studies is \$1M, with each to be about \$100K (5-8 studies). Final deliverables are to the Decadal Survey Committee. NASA plans to ask the Decadal Survey Committee to recommend a line of Astrophysics Probe class missions, or specific mission objectives, or more detailed concept studies for a small number (2-3) studies. APS concurred

with these plans. APS also carried out its GPRAMA exercise, unanimously agreeing that NASA performance goals were Green.

On the subject of Hitomi, given the successful demonstration of the TRL 9 performance of the SXS, the APS formally recommends that APD proceed rebuilding the SXS (\$70-90M), provided efforts were made on the part of JAXA to mitigate risk of another catastrophic failure, and that the mission be in accordance with the goals of the Decadal Survey and the conclusions of the mid-decade review. Dr. Gaudi asked that this formal recommendation go forward for Science Committee approval, while JAXA investigates best practices to avoid future failures. APS feels that JAXA is making good progress in understanding lessons learned.

Dr. Peterson asked if a proposed Probe line would jeopardize chances for Flagship missions. Dr. Gaudi noted that there are concerns in both directions; i.e. Flagships taking up all the money, or Probes preventing Flagships. There are different opinions on what a balanced portfolio looks like; this is a job for the Decadal Survey. Dr. Jernigan remarked that the next Decadal Survey would reportedly take into account the effects of large mission overruns. Dr. Gaudi replied that all four large missions will be independently cost-estimated and technology-assessed. While the greater calls for independent cost analysis and technical evaluations (CATEs) were in direct reaction to the JWST experience, the culture has changed significantly in the last decade. There are definitely New Frontiers-scale missions that APD wants to do; e.g., a starshade to accompany WFIRST would fit in this Probe class, which currently doesn't exist. Dr. Gaudi felt it likely that the Decadal Survey would recommend a Probe-class line. Dr. Peterson felt this was congruent with past calls to increase Explorer success rates, as per prior Decadal Survey recommendations. Dr. Neal thought that \$100K for concept studies was a bit low. Dr. Gaudi noted that APS felt it might not be enough money for in-depth studies, but it made no formal recommendation on the matter.

Earth Science Division Update

Dr. Michael Freilich, Director of the Earth Science Division (ESD) presented a status report. The budget for FY16 is roughly \$1.9 billion, with an expectation of about \$2 billion per year through the outyears. There are four elements of the ESD: research, flight, applied sciences and technology programs. The flight program monitors and observes the Earth from space, carries out research to understand the Earth as an integrated system, and develops and tests new information products tailored to needs of end-users. There are 19 Earth science missions on orbit, many on extended missions, and an equivalent number of satellites and instruments in development for launch between now and 2022. ESD is reinvigorating its spaceborne observation system as per Decadal Survey recommendations, and developing Earth science instruments for deployment on the ISS. Since the last meeting, there have been regular major mission gate reviews, including for OCO-3 (Orbiting Carbon Observatory-3) and SWOT. Key decision points (KDPs) are coming up for RBI (Radiation Budget Instrument), NISAR (NASA-ISRO Synthetic Aperture Radar), and ICESat-2 (Ice, Cloud, and land Elevation Satellite-2). There is a lot of activity to move these missions forward. The Venture class program remains fully funded and on schedule; the latest instrument solicitations are MAIA (Multi-Angle Imager for Aerosols) and TROPICS (Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats). MAIA is a polarimeter, and marks the first time a spaceborne instrument is measuring concentrations and types of aerosols and

how they relate to human health characteristics, with frequent high-resolution measurements of at least ten urban areas around the world. TROPICS is a 12-CubeSat constellation that will complement the CYGNSS (Cyclone Global Navigation Satellite System), making sounding measurements in rapidly evolving storm systems, with 30-minute resolution (far more frequent than previously possible) for a low cost of \$30M.

The Earth science research element is focused on the carbon cycle and ecosystems, and includes discipline-oriented activities within focus areas, interdisciplinary and cross-cutting activities, competed mission and measurement science teams, and enabling capabilities, including airborne assets, space geodesy, global modeling, Congressionally mandated carbon monitoring, and High-Performance Computing (HPC). Over the next year, the ESD R&A program will support a large number of field campaigns.

The Applied Sciences program and its four sub-elements are focused on societal issues: Applications, Capacity Building, Satellite Mission Planning, and Program-wide activities. Applications-associated programs such as SERVIR (in partnership with USAID) will be expanded through 2017-21 to include six hubs, and funding will be increased to serve more areas around the world. In June, the Applied Sciences Remote Sensing Training (ARSET) program held three concurrent web training sessions in health monitoring, disaster management, and forest cover and change assessment, reaching over 1000 trainees in one day.

The Earth Science Technology Office (ESTO) has five activities: Instrument Incubator Program (IIP), Advanced Component Technologies (ACT), Sustainable Land Imaging-Technology (SLI-T), Advanced Information Systems Technology (AIST), and InVEST, the last a CubeSat-based technology demonstration program. The Small Satellite Constellation Initiative is a one-time \$30M initiative (FY17) meant to expand the use of data from constellations of small satellites. CYGNSS and TROPICS have been selected for this initiative, which will also leverage the commercial and private sectors. To this end, NASA has sent out a broad RFI to identify existing or near-term nongovernmental products derived from small satellite constellations. ESD is prepared to spend some of this funding on pilot activities, such as radio occultation and land imaging. It also may use some of this funding to support small launch vehicles for small payloads in the Venture class.

A new Satellite Needs Working Group has been created to help inform NASA, the civil space agency with the mandate to make non-meteorologically focused measurements for all other U.S. agencies. The working group transmits the needs of other agencies to NASA on an annual basis. NASA then examines the needs, and works them into the portfolio insofar as it is possible to accommodate them. Starting next year, ESD will have to show the Office of Management and Budget (OMB) how NASA adjudicates the requests from other agencies, and what percentage of the needs are being met for each agency.

The Earth Science and Applications from Space (ESAS) Decadal Survey 2017 is in progress, co-sponsored by NOAA/National Environmental Satellite, Data, and Information Service (NESDIS), USGS, and NASA. The final report is due at the end of 2017. A number of other boards are participating with the Space Studies Board (SSB): atmospheric sciences, polar research, ocean science, hydrology, and solid

Earth. Dr. Freilich solicited the ESAS Committee for additional ideas on the Global/Hydrologic Cycles, Earth Surface and Interior, and other themes, because this Decadal Survey will be much more focused on measurements rather than very detailed missions. The outcome will likely require some sort of roadmapping process to implement. ESD has asked specifically for recommendations on balance among the full suite of Earth system science research areas. Named missions from the previous Decadal Survey will be reassessed as to their scientific priorities.

There are six field investigations ongoing in the airborne program. During 2016, there have been six sea science flights and ten land ice science flights, overall averaging 3.6 science flights per week. This is an immensely successful scientific program. The Korea U.S.-Air Quality (KORUS-AQ) campaign has made measurements of air quality at eight major ground sites, using three aircraft. ESA, Korea and NASA will be continuing this experiment over the next few years.

Dr. Avery expressed concerns about the subseasonal theme area in the Decadal Survey, and asked if NASA was watching how the National Academies evolves these topics to obtain the right system elements. Dr. Freilich stressed that the Decadal Survey is independent, however given the timescale of the topics, he expected that it would recommend elements that span the necessary continuum and ensure against gaps. Dr. Avery also was concerned about balance of applied work against frontier research. Dr. Freilich said NASA has explicitly asked the Decadal Survey to look at this balance. He noted that the ESD Applied Sciences program gets a disproportionate amount of attention for its total funding of \$40-60M per year. This comprises 2.5% of the ESD budget, but it makes a tremendous contribution. The Satellite Needs Working Group and the desires of other agencies is an experiment—NASA is not obligated to implement these other desires, and only is obligated to show how it can address them. Dr. Freilich hoped to be able to implement these needs at modest cost.

Discussion with the SMD Acting Associate Administrator

SMD Acting Associate Administrator Mr. Geoff Yoder addressed the Committee, and detailed the integrated approach that he has adopted for the Directorate. In addition to weekly one-on-one meetings with the division directors, he also has set up a group in SMD that includes the NASA Chief Scientist and Chief Technologist, along with the four division directors. This group's purpose is to address integration across all divisions through strategic planning to further advance NASA objectives and Decadal Survey goals. To advance the state of the art in each mission, SMD now is looking to incentivize and validate new technologies on existing missions, and keep this the focus for ongoing discussion. Three of five Discovery missions are taking technology demonstrations on in an effort to advance this integrated focus, to reach students and generate the global excitement that NASA is known to be able to generate. SMD has an integrated program enabling rich science, with interconnecting fundamental science questions to help understand the origins of life and whether or not we are really alone in the universe. Citing the Magnetospheric Multiscale (MMS) mission as an example, Mr. Yoder wanted to disseminate the message that a heliophysics mission helps to answer science questions throughout SMD: solar dynamics for heliophysics, space weather for Earth science, the history of water on Mars for planetary, and stellar formation for astrophysics. He looked to the SC to make suggestions as to how to get this message out, and to issue similar messages for other missions, showing how science questions are intertwined.

SMD communication priorities are focused on themes such as Earth Right Now, the uses of ISS, and Mars, specifically, the Journey to Mars. SMD drives professional science and also popular science, providing science findings to excite the next generation. The New Horizons Pluto flyby generated tremendous excitement, with 12 billion social media posts. OSIRIS-REx is another opportunity for generating public interest, as are CYGNSS and GOES-R. SMD is maintaining a balanced approach among NASA's spacecraft, CubeSats, Earth-based investigations, suborbital and balloon payloads, technology development, and research (10,000 U.S. scientists funded, \$600M awarded annually). NASA partnerships are also valuable in this regard -- 60 countries and 475 agreements. SMD helps to inform international disaster relief efforts. SMD is committed to ISS partnerships, with 13 instruments on or scheduled to go on Station. SMD also is partnering with HEOMD for DSN and launch services.

Overall SMD is collectively under its commitments by about 1%. In HPD, the Decadal Survey missions ICON (Ionospheric Connection Explorer) and GOLD (Global-scale Observations of the Limb and Disk) are flying as hosted payloads, emblematic of how NASA should look for spare mass capabilities on other future missions. ESD CubeSats are another example. The entire community should take pride on the science returns coming out of the SMD portfolio. SMD continues to work to ensure a continued balance across its 114 space-based science missions, active or in formulation, and to maintain a healthy cadence distributed among launch vehicle platforms.

SMD provides numerous benefits on Earth that should be communicated to non-scientists. NASA provides benefits such as better prediction of hurricanes and weather; fire monitoring; crop health and water use efficiency; improved space weather monitoring to protect global power grids; and increased understanding of asteroids and comets.

Dr. Jernigan suggested including a "top ten" list of scientific discoveries (e.g., over a period of time), and felt that the Juno example in particular was useful. Dr. Lindberg recommended highlighting the significant support that NASA provides to educators, undergraduate and graduate programs, and K-12. Dr. Peterson also appreciated how Juno helps to inform problems in astrophysics. Dr. Gaudi noted that when APD did its roadmapping exercise, it took a look back and highlighted how NASA has contributed to answering science questions, emphasizing to the new generation that they can be part of this process. Dr. Peterson added that JunoCam makes the missions real for people, even though it is a non-scientific addition to the mission. Similarly, the lunar camera for Apollo 11 had been an afterthought; SMD should be aware that the missions are not just about scientists. Mr. Yoder agreed, citing the inclusion of a microphone on the M2020 rover. Dr. Robinson felt that tracking long-term climate trends should be added to the list of benefits. Dr. Avery seconded this idea, adding that NASA really has tied it together with measurements and modeling, and has also brought other agencies into the process. NASA will play a key role in this generation's future. Dr. Neal cited the late Dr. Mike Wargo's phrase, "science enables exploration and vice versa," noting that science from deep space missions yields data that will help to push humans further out into space. Thus, it's important to keep that cross-directorate synergy and emphasize that SMD informs HEOMD and vice versa. Dr. Neal also brought the fragile performance of DSN to Mr. Yoder's attention. Mr. Yoder said he was having this discussion now with HEOMD Associate Administrator Bill Gerstenmaier and agreed that the problem needed to be solved. Dr. Avery pointed out that NASA also enables the science process, which is very different from bench science.

NASA is a science organization that uses observations, and can do things that a reductionist bench scientist can't do. This inductive approach enables our ability to explore.

Mr. Yoder and Dr. Peterson concurred on the great value of Flagship missions such as HST, which have proven to yield unexpected science discoveries. Dr. Jernigan agreed that NASA's great observatories are the gold standard. Asked how much he was interfacing with media, Mr. Yoder reported he had appeared on national television for the Juno event, and briefed the Aerospace Industries Association (AIA). He realized that science presentations are not one-size-fits-all and has been tailoring his message to the audience.

Dr. Neal noted that SMD must integrate the planetary protection aspect into the message, as it bears heavily on the Journey to Mars and human exploration in general. Dr. Lindberg noted that communication between the PPO and PSD has improved in this matter. Dr. Peterson observed that the NAC must decide where PPS will reside in the infrastructure, adding that the decision has a practical aspect, as SC receives recommendations from PPS. Mr. Yoder said that there is a look at the overarching structure to see how to proceed. Dr. Peterson was concerned that recommendations will get lost in the transition process. Mr. Yoder noted that standing review boards (SRBs) currently lack planetary protection experts, and aimed to take this into account as the committee structure evolves. Dr. Neal stressed that planetary protection needs to be focused on as a priority going forward; it will affect MSR, among many other missions. Dr. Lindberg felt it may be time to have another joint meeting with the NAC Human Exploration and Operations Committee (HEOC) on this matter. Dr. Peterson raised the importance of how the landing site of the Mars 2020 rover might affect where humans might eventually go on Mars. Mr. Yoder noted that the site selection for human exploration is needed before Mars 2020, and that SMD was working with the scientific community and HEOMD. Dr. Lindberg noted that SMD concerns should point out astrobiology and the search for origins of life, and was interested to see that JWST has among its science objectives measurements related to origins.

Discussion

The SC discussed the PSS finding on Principal Investigator (PI)-led labs. It was considered to remain a PSS item and did not proceed further.

On the subject of PPS-PSS joint work, the SC decided to issue a finding that would proceed to the NAC. Drs. Neal and Lindberg agreed to draw up some words for a finding on holding a joint PPS-PSS meeting. Relatedly, Dr. Lindberg noted that there may come a point when planetary protection does not reside in SMD if there are activities also going on in HEOMD and STMD; and PPS has recommended this. Ideally, the PPO should play more of a safety and mission assurance function as an independent line of authority, to foster a healthy tension between mission success and mission safety. He felt that this issue could be brought to the NAC again. Dr. Neal felt the Journey to Mars could act as a catalyst to such a move.

The SC considered a finding on clearer communications about MSR, with possible ties to a discussion about a sample receiving facility (SRF), which most acknowledge requires a minimum of ten years'

development time. Thus far, SRF discussions have not progressed significantly. Dr. Neal said he wanted this on the radar for now, as PSS needs to confer PPS before it can go any further.

Member Research Presentation “Completing the Census of Exoplanets with WFIRST”

Dr. Gaudi presented the member research presentation lunch talk, focused on completing the census of exoplanets with WFIRST. Dr. Gaudi noted the level of understanding of physical processes of planet formation, and then detailed the contributions of the Kepler mission in observing confirmed planets and candidates. He emphasized the ground-breaking nature of the new technique of microlensing in completing the census of exoplanets (e.g. planets beyond the snow line, very low mass planets), and provided an animation of microlensing planet detection. The WFIRST microlensing exoplanet survey will be one of the main science capabilities of the mission; plus, the telescope’s search area is much greater than that of Kepler. WFIRST will enable qualitatively new, exciting science: sub-Earth-mass planets, free-floating planets, outer habitable zone planets, and mass measurements. Dr. Jernigan inquired on the scale of the WFIRST telescope that accomplishes this, and Dr. Gaudi mentioned that it barely fits in a Delta-IV Heavy. Dr. Robinson inquired about false positives and Dr. Gaudi explained that the signals will constitute stars that are observed for five years without significant deviations, and then exhibit a localized deviation consistent with the known shape of microlensing event; instrument artifacts are not expected to exhibit this behavior.

Heliophysics Division Update

Mr. Steve Clarke, Director of the Heliophysics Division (HPD), presented an update. Operating missions are doing well, in general. STEREO-B (Solar Terrestrial Relations Observatory-Behind) (partner satellite to STEREO-A, for Ahead, orbiting the Sun) is still silent, although NASA will continue to ping it once per month through the next year; if it doesn’t respond, NASA will try again in 2020. The Interstellar Boundary Explorer (IBEX) star tracker issue has been resolved, as has a similar issue with MMS. The Interface Region Imaging Spectrograph (IRIS) star tracker problem is to be resolved soon. In the Solar Terrestrial Probes program, MMS has been flying for over a year and is continuing to provide data. The Interstellar Mapping Probe (IMAP) (2023) is currently the subject of an AO, set for release in 2017. In Living With a Star (LWS), the Space Experimental Testbed (SET) launch scheduled for September 2016 has been changed to no earlier than March 2017, flying on a Falcon 9 heavy as a secondary payload; the demonstration for the heavy vehicle had been delayed. SPP, scheduled to launch in July 2018, has completed radiator fabrication, and its four instruments are in varying levels of testing. The Explorer mission ICON is set to launch in October 2017, and possibly earlier. All instrument testing has been successfully completed; a noise issue with the reaction wheel assembly was quickly resolved. The Explorer GOLD, scheduled for April 2018, may also launch earlier. GOLD is making good progress and just completed vibration testing, and passed a critical design review (CDR) on June 29. A SMEX and MoO AO were released in July. The Gamma-Ray Imager/Polarimeter for Solar flares (GRIPS) balloon experiment completed a successful campaign. The NASA/ESA Solar Orbiter Collaboration (SOC) mission completed a delta-CDR on June 9; ESA released an AO for the SOC-related SPICE instrument operations on June 27. NASA is contributing two instruments to SOC; while it is still concerned with the ESA mission schedule, Mr. Clarke believed conditions were improving. The launch readiness date remains October 2018.

HPD's sounding rocket schedule is busy from June of this year through March 2017. Mr. Clarke noted that a scheduled High Resolution Coronal Imager (Hi-C) launch did not occur last week due to a faulty rocket guidance system. The issue was a software problem that has been resolved, and the launch is re-scheduled at White Sands for July 27. Another recent launch of note was a Rocksat-C student mission, launched successfully on June 24 with more than 100 students and educators participating. The HPD ROSES 2015 call is complete; the average success rate was 18%, somewhat increased from 2014. The 2016 ROSES call has been released, for which reviews will be ongoing into the Fall. Mr. Clarke reviewed the HPD budget for FY16: 11% of funds are allocated to research, 54% to missions in development, 12% to operating missions, and 11% to suborbital. Missions in development are fully funded; future mission funding will include an Explorer AO/MoO in FY16. The budget is allowing an increased cadence for the community. Mandatory spending from OMB for FY17 includes \$10M for the heliophysics CubeSat program, \$10M for space weather research, and an additional \$5M for R&A.

A National Space Weather Action Plan and Strategy were established in October 2015. The Action Plan details the activities, outcomes and timelines that will be undertaken by Federal departments and agencies for the Nation to make progress toward six strategic goals. These are: establish benchmarks for space-weather events; enhance response and recovery capabilities; improve protection and mitigation efforts; improve assessment, modeling, and prediction of impacts on critical infrastructure; improve space-weather services through advancing understanding and forecasting; and increase international cooperation. NASA is providing space weather expertise to support 40 actions related to the six goals of the Plan. NASA has been working well with NSF, NOAA and DOD, supported by memoranda of understanding. Future modeling of Research to Operations (R2O) and Operations to Research (O2R) concepts is being matured. International collaborations associated with the Plan include the chartering of a working group at the Korea Astronomy and Space Science Institute, with a potential for collaboration in data analysis, modeling and flight projects; and a JAXA/ESA multilateral science objectives team that has been convened to meet Solar-C objectives. The team has three co-chairs, 12 members, and held a kickoff meeting on 13 July. NASA engages with team once every two months; and with an Indian Space Research Organisation (ISRO) working group, which is focused on modeling solar activity, joint observations and data analysis, and ground-based observations.

Heliophysics Subcommittee Report

Dr. Jill Dahlburg, the Chair of the Heliophysics Subcommittee (HPS), provided a brief report, first showing some image data from the Hinode satellite, featuring extreme ultraviolet images of a coronal loop. HPS has three new members, and one member is rotating off. The next meeting will be in August, most of which will be devoted to performance assessment (GPRAMA) in thematic areas of heliophysics: exploration; advancing understanding the Sun-Earth connection; and developing knowledge and capability for societal benefit. Dr. Dahlburg presented two significant science highlights from the Van Allen Probes mission studying the Earth's radiation belts, one of which resulted in an article in *J. Geophysical Research* (Dr. Ramona Kessel, NASA HPD), and Kistler et al.'s article in *J. Geophysical Research in Space Physics*. Lastly, Dr. Dahlburg displayed extreme ultraviolet images of the Sun showing the distribution of silicon, iron-12, and iron-15 at solar minima and maxima.

Dr. Robinson asked if there were good models of what happens to field lines during extreme events. Dr. Dahlburg said there are suggestions that field lines could be pushed back far enough to expose satellites to the direct solar wind. Responses have been seen in oil pipelines and grids, and there has been an event where aircraft using GPS had to be grounded. MMS and ICON are two missions important to understanding this effect. In response to a question, Dr. Kessel commented that the solar storms cause the radiation belts to get pumped up with high energy electrons and those can damage satellites (e.g., arching, single event upsets). The Earth's magnetic field permeates the crust of the Earth, and extends millions of miles out into space. She didn't think the field and hence radiation belts have ever been known to get squashed in as low as the Earth's atmosphere.

Ad Hoc Big Data Task Force

Dr. Chuck Holmes, Chair of the Big Data Task Force (BDTF), presented a report from a June meeting at the Goddard Space Flight Center (GSFC). The BDTF has two new members, Drs. Eric Feigelson and Ashok Srivastava. At its inaugural meeting, the BDTF had heard a briefing on the NSF's Big Data Regional Innovation Hubs, a project that is on a three-year contract timeline. Since that first meeting, BDTF members visited key personnel in each of the four Hubs, as well as NSF itself. Dr. Holmes also spoke with NASA's Dr. Max Bernstein about the process for alerting the NASA research community through ROSES to sponsor collaboration with these Hubs. Because the selection of grants is in process, the Task Force tabled further discussion of the Hubs until after the announcement of the associated NSF "Spokes" grants. During the June meeting, BDTF adopted a work plan with four case-study topics, to be followed by research and development of positions and consensus. The Task Force also heard a briefing from APD's Dr. Hashima Hasan on the outcome of a peer review of the Astrophysics Data System (ADS). A May 2015 Astrophysics Archives Program Review had expressed serious concerns about the infrastructure, bandwidth, budget, and creeping obsolescence of ADS, after which APD took actions to improve its archives, and which were represented to good effect in Dr. Hasan's briefing. Briefings from Goddard's High Energy Astrophysics Science Archive Research Center (HEASARC) indicated that the archive had responded well to recommendations, and that currently, about 10% of the total astronomical literature depends on its data. The BDTF heard from the Mikulski Archive for Space Telescopes (MAST), which holds a diverse grouping of data from HST and Kepler, among other missions, and which also has absorbed data from the PanSTARRS (Panoramic Survey Telescope and Rapid Response System) project (1.9 billion objects). BDTF notes that the archive must evolve with the increasing capability to accommodate forthcoming missions such as WFIRST. MAST is working on server-side scripting machine language to allow users to further refine their searches and do more advanced hypothesis generation before downloading any large data sets.

The NASA Center for Climate Simulation (NCCS) is analyzing how to separate features of high-performance computing (HPC) and data analysis in order to more efficiently use the center's capacity. Big data analytics needs a different infrastructure than HPC, which enables traditional use of data and a dramatic reduction in data movement. NCCS is evolving its services using commercial "big data" technologies such as virtualization, Hadoop and MapReduce, and Object Store. A major challenge is that these technologies don't integrate well with scientific or binary data. The Climate Science Data Analytics group also briefed the Task Force, as did the Earth Observing System Data Information System (EOSDIS), which is now looking at commercial cloud-based projects, and has created an analysis toolbox

to attract experimentation. The take home message is that cloud prototypes are under way to attack the volume challenge of big data, but advances in hardware or cloud won't help much with variety. Standards, conventions and community engagement remain the key to addressing data variety.

The Planetary Data System (PDS) is managed at GSFC with data nodes distributed around the U.S. PDS has developed a new data format standard, PDS4, which has been adopted readily by international partners as a standard for planetary data. PDS is conducting a Planetary Cloud Experiment, testing with Amazon and other services. In Heliophysics, BDTF heard from the Solar Data Analysis Center (SDAC), which reported that while data volume is currently manageable, future missions such as the Daniel K. Inouye Solar Telescope (DKIST) will be contributing large amounts of data, and SDAC is unlikely to be the long-term archive for Solar Dynamics Observatory (SDO) data. The Task Force plans to go to Stanford to investigate the issue further. The Space Physics Data Facility (SPDF) is used by the community to a very significant degree, and is doing well. The Community Coordinated Modeling Center (CCMC) runs dozens of models (from the Sun's corona to the ionosphere/thermosphere) via a Runs-on-Request System. Dr. Holmes felt the CCMC to be an unheralded success story at NASA that other communities might want to utilize.

Dr. Larry Smarr briefed the Task Force on the Pacific Research Platform (PRP), which is building on a fiber optic infrastructure developed by the CENIC (Corporation for Education Network Initiatives in California) program over the last 15 years. The CENIC line has allowed university campuses to connect to a large high-speed network via Flash I/O Network Appliance (FIONA) Linux-based devices, at a very low cost. The program is now trying to connect nationally with DOE's Exoscale Network through Lawrence Berkeley National Laboratory. This is very exciting work, and the BDTF hopes to develop recommendations for SMD to take advantage of this network.

Over the next year, BDTF will work on four focus topics, the first of which is Data Discovery. The goal is to assess the current level of accessibility to NASA's science data across the board, and identify common problems where cooperation among the disciplines might lead to better solutions. BDTF is also looking at Improved Data Analysis Methodologies, for recommending actions on architectures and strategies to do this. Modeling Workflows will assess workflow chains, which have not changed much since the 1970s. Findings and recommendations in this area will help NASA make more effective use of both its internal and external computing resources, and to achieve shorter time to solution for modeling-focused research. The Case for Adopting Server Side Analytics explores the idea is that some big data sources will need to establish a tailored processing ability, change the architecture for analyzing large data sets.

BDTF Findings:

1. Formatting evolutions - Evolution of data standards for NASA science data has helped to advance data management, improve data descriptions, and promote better access to data in the future.
2. The ADS is a large, bibliographic web-based system that serves all of SMD, and also is freely available to the public.
3. The HPC group at NASA demonstrated a strong understanding of the current paradigm shift.
4. Pacific Research Platform and big data science was found to be very important work—this a “soft” recommendation for the present.

Dr. Holmes summarized with a “soapbox statement,” observing that the Goddard projects are not resting on their laurels, and they are doing exceptional jobs within their budgets. He sought guidance from the SC on how to pursue BDTF findings.

The SC assessed the findings. Dr. Robinson commented on formatting evolutions and asked how legacy formats were treated: Do they get converted? Dr. Holmes replied that the ability to convert these data is resource-limited, and agreed to try to get an answer to this question for the next report. The SC declared formatting evolutions as a to-be-determined matter and the finding was sent back to the Task Force. As to the ADS finding, Dr. Gaudi mentioned that the system is used daily, and Dr. Lindberg added that it needs an upgrade. It was agreed that APS would continue to monitor the subject as a concern, and also a SC finding on ADS would be brought to the NAC. Regarding the HPC finding, Dr. Lindberg noted that Goddard has done a great job. The HPC finding was well supported by the Space Physics Data Facility chart on big data usage. The finding did not go further. Regarding Pacific Research Platform finding, the SC felt that independent evaluations of the FIONA tool would be necessary before recommending a particular system. Dr. Peterson agreed to express this finding as a good example of potential work. He also informed Dr. Holmes that he had circulated his notes on DSN. Dr. Robinson asked what happens to raw spacecraft data (telemetry packets from spacecraft to data). Dr. Holmes noted that BDTF hasn’t looked at this specifically. Dr. Robinson said the question arose from concerns about an error in unpacking data. Dr. Holmes found the concern a little hard to believe, given existing standards.

Joint Session with the Ad Hoc Task Force on Stem Education

Ad Hoc Task Force on STEM Education

Dr. Peterson announced that this was the first joint session of the Science Committee and Ad Hoc Task Force on STEM Education and asked the members to introduce themselves.

Dr. Anita Krishnamurthi, Chair of the Ad Hoc Task Force on STEM Education, provided a briefing to the SC. The STEM Task Force has seven members and reports directly to the NAC. Dr. Krishnamurthi gave some historical background on the NASA Office of Education and its transformations over the last decade. There is no current external advisory committee for the office, but there is an Education Coordination Council (ECC), an internal group that guides education. NASA Education has been directed to do quite a bit under the 2015 America COMPETES (Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science) Reauthorization Act, and there’s been an ongoing consolidation effort in reaction to this act. In 2015, there were two major education programs: the Aerospace Research and Career Development (ARCD) program, and STEM Education and Accountability (SEA) program, which is relatively undirected. Education has four lines of business: STEM Engagement, Educator Professional Development, NASA Internships and Scholarships, and Institutional Engagement. Key stakeholders and influencers are mission directorates, legislative and Executive branches, regulatory bodies, etc., that represent a lot of push and pull on the office. STEM engagement’s stated mission is to advance high-quality STEM education using NASA’s unique capabilities. There is also an education objective in the NASA Strategic Plan. The planned education strategy is to use the ECC to direct the Agency effort in STEM, and NASA has been making efforts to

partner with other agencies to leverage existing programs. There is tremendous pressure to collect data and metrics for OMB to describe NASA's return on investment.

Under ARCD, there are two major projects: Space Grant, and the Experimental Program to Stimulate Competitive Research (EPSCoR). SEA program projects include the Minority University Research and Education Project (MUREP), and the SEA Projects (SEAP). SEAP has about \$25M, the only undirected pot of money at NASA for education. This is what is available for solicitations and competitions. EPSCoR is primarily concerned with institutional engagement. The Task Force has been discussing whether the programs and projects are spread too thinly, but has found it interesting to note that there are many success stories highlighted in the media. Agency-wide, there are 39 partnership agreements, such as Honeywell's hip-hop STEM program, a CubeSat deployment under HEOMD, and a Girlstart afterschool program. There is also the Museum Alliance, incubated by SMD and adopted by the Office of Education. Education is a very tiny fraction of the NASA budget of nearly \$20 billion. Despite this, the education budget request has been decreasing, and is down substantially from \$145M in 2011. The Senate and House have proposed education funding that differs two-fold in quantity.

The Task Force has been assessing whether NASA Education is doing too much with too little. At the same time, NASA established the Business Services Assessment (BSA), which is examining how business is done in education. It has been determined that BSA is looking at the "how," and the Task Force is trying to provide recommendations on the "what" of education. The BSA will address two goals: assess NASA's capability to advance high-quality STEM education and engage the public, and evaluate the health of NASA's current education and outreach (E&O) functions. To carry out this work, the BSA Core Team has gathered a number of subject matter experts (SMEs) and non-SMEs; developed a data call process and questionnaire; and will develop findings for an August/September presentation.

The STEM Task Force has developed recommendations targeted to the NAC:

- NASA should form a high-level external advisory committee for education.
- NASA should identify a strategic focus for non-directed dollars (e.g., age groups, geographic areas).
- NASA should actively support and engage NASA grantees to connect to the broader STEM education community.
- NASA should collect and utilize data to inform solicitations and strategic directions for NASA's education programs.

The Task Force also posed the following questions for the BSA: Are NASA's education efforts providing the best possible outcome? Is there shared ownership and trust? Authority and accountability? Are resources allocated appropriately? Does the Office of Education have the capacity to be successful?

Joint Discussion SC and STEM Education Task Force

Dr. Lindberg noted that SMD solicitations once required that the mission PI propose some E&O activity; however, over time it was decided that these activities lacked standards of learning (SOL)-related value. Should PIs engage with STEM professionals to transmit some of this knowledge? This works better pedagogically. Dr. Krishnamurthi felt such an approach also would enhance communication to help both education and research grantees become involved with the existing STEM education community.

Dr. Ray Mellado noted that it was important to collaborate and create the nexus within universities, and cited a particular example of the University of California's STEM education department that reports to the college of engineering. It internally funds faculty research in STEM. Dr. James Marshall Shepherd reported that at the University of Georgia, outreach to K-12 students is being done, and many universities are leaning in that direction. Dr. Carl Person noted the importance of building capacity at minority serving institutions. Dr. Avery asked how to define the broader STEM community, and requested that the Task Force pull together a list that defines this community, for the benefit of grantees. Dr. Krishnamurthi agreed that the definition needs to be more specific. Dr. Mellado posed the question of how to get the information out without using NASA resources. To get information to the broader community, Dr. Krishnamurthi noted that the goal of the Museum Alliance, and the Department of Education After-school program is intended to feed content into STEM projects, to build a broad base of knowledge. Dr. Robinson felt it was better to have human contact for this task (a PI to an audience).

Dr. Pieters observed that using NASA's workforce in promoting the goals of education seems to be more of a formalized process, ensuring diversity goals are met. However, she felt the endeavor was much more personal for the NASA workforce, to communicate their excitement and enthusiasm. These are two very different approaches, and it is not obvious how this fits into a formal education program. Ms. Beverly Girten, Executive Secretary of the STEM Task Force, agreed that a disconnect has occurred as a result of mandated education changes, which has decreased direct engagement with NASA scientists and engineers. The BSA may look at this issue. The other issue is an NASA Policy Directive (NPD) that addresses education efforts linked with the missions, which may help enforcement. She noted that the ECC does have representatives from every mission directorate to help determine how to engage with PIs and the NASA workforce.

Dr. Lindberg related that as a PI at a NASA center, he had personally seen the education team engaged with the science and engineering teams. However, that connection may not get made as effectively at an academic center. Dr. Shepherd completely agreed that centers are usually very well connected to E&O, and during his first twelve hours at Goddard, he was part of a team. He feels the disconnect now that he is at a university, without those resources. Dr. Krishnamurthi thought this was an interesting point to note—what is the burden on the PI when s/he doesn't have the resources at a NASA center? Dr. Avery said that if these are important criteria, universities should build in the infrastructure to provide bridging and support, so that the expert is not burdened by STEM duties. This could be built into the overhead cost at the university. Dr. Krishnamurthi asked if it would be useful for NASA Education to recommend infrastructure to plug into. The Museum Alliance might be one source, or perhaps it would be useful to engage the NASA workforce to serve as role models and mentors.

Dr. Jernigan noted that her experience with NASA indicates that many staff already donate their time; the bigger issue was packaging content for use in the classroom. Dr. Pieters thought that while scientists and engineers are deeply involved, they are not always good communicators. She felt it was possible to provide small resources, whether it is printing images or going to schools, but didn't see that this is being done. Ms. Mary Sladek of SMD commented that SMD now emphasizes SMD as source of both content and SMEs. The push to teach by mission is not how it is done at the K-12 level. SMD is restructuring the

previously mission-based education efforts, and has supported evidence-based activities through the late 2015 selection of new cooperative agreements made through the SMD Science Education Cooperative Agreement Notice. NAS and OMB recommend evidence-based practices, such as quasi-experimental designs, and treatment protocols/control groups, to better demonstrate the efficacy of learning methods for students and professional development for teachers. She noted that the Department of Education maintains a What Works Clearinghouse. Research also seems to indicate that teachers need to be supported in the classroom in order to implement what they've learned in professional development. Dr. Peterson commented that he'd mentored a research student who had one of these K-12 STEM grants, and found that the time and effort required to make the teaching program effective seemed disproportionately large for the small number of children impacted.

The Committee considered options for going forward on STEM education. Ms. Denning noted that the a STEM Education seat, in addition to the existing Public Engagement seat, has been added to the SC due to SMD's high interest in the subject; the next step is to work on mechanisms for action. Dr. Peterson said that if NASA wants to inspire the next generation, it must do something spectacular, on the level of the Apollo program. Dr. Shepherd felt that demographics also needed to be taken into account.

Dr. Jernigan suggested putting products and tools in the hands of the teachers, which provides a lot of leverage in low-income areas. She thought HST had helped NASA get smart on communication as a high-leverage investment, and suggested there may need to be some bridging effort for scientists who are not good communicators. Dr. Robinson requested more information on evidence-based educational activities so that NASA could improve what it distributes. Dr. Pieters suggested that NASA do something as simple as adopting the metric system, to lead the way. Dr. Avery asked if education goals tended to be too broad and too much given the budget. She recommended a focus on evidence-based activities, or concentrating on minority-serving institutions to get undergrads into graduate school. Most of the funding to support minority graduate students is coming from NIH—where is the physics and mathematics? NASA has some of this scaling to do to have an equivalent program. Dr. Lindberg urged the NASA Education Office to fund professional development resources that are evidence-based and aligned with local standards—the teacher is the first multiplier of learning and will have an impact that lasts for a period of years. He felt NASA should abandon efforts to reach students directly at the K-12 level. Dr. Peterson asked if NASA could teach teachers without getting bogged down in “education-ese.” Teachers should be able to describe how an orbit works. Dr. Lindberg cited the NASA eclipse program as exemplary for providing professional development.

Dr. Peterson deferred a finding on education to the next meeting. Dr. Krishnamurthi noted that the Task Force would consider where they see the interplay with SMD Education, and what can be done together. Dr. Peterson affirmed that the SC will iterate further with the Task Force. Dr. Pieters mentioned that the solar eclipse might provide an opportunity.

Public comment period

No comments were noted.

July 28, 2016

Discussion and Wrap-Up

Ms. Denning opened the meeting and the new NASA planetary protection video was shown. The Committee briefly discussed why Ganymede is not considered as equivalent to Europa in terms of planetary protection categorization. Dr. Catharine Conley, NASA Planetary Protection Officer, commented that the ESA JUICE (JUperiter ICy moons Explorer) mission did an analysis of Ganymede and determined that the habitat was not endangered. As for Titan, Dr. Conley noted that the Huygens spacecraft was not clean, and at the time of the mission, evidence of water on Titan was unknown. Dr. Robinson felt that Ganymede should be considered as potentially contaminable, on an equivalent basis to Europa.

The committee discussed seven potential findings and recommendations. Members took up the recommendation on regular coordination and communication between PPS and PSS to keep abreast of astrobiological issues associated with sample return from bodies in the Solar System, with regular updates to the NAC. Dr. Pieters noted that most sample return missions have a cadre of scientists on the case, and that this is currently not the case for the M2020 sample return. Scientists must be deeply involved in the MSR entire process. Dr. Neal noted that this was the intent of the recommendation. Dr. Lindberg agreed that there is a concern that scientists be involved as per Dr. Pieters' comment, but that the recommendation addresses the broader issue of communication between the two communities. Dr. Conley commented that the PPO has been having discussions with curation, which also addresses the concerns about science content. Dr. Gaudi felt it unlikely that a mission would be launched without scientific vetting, and that the point was the process be initiated earlier in mission planning. The recommendation was approved.

The Committee concurred on carrying forward the APS recommendation on Hitomi as a SC recommendation, to be strengthened by adding the importance of Decadal Survey support.

A recommendation from the BDTF on modernization of the ADS was deemed a SC finding to be forwarded to the NAC, and also be brought back to the APS for further investigation, and may potentially be made into a recommendation afterwards. Regarding the BDTF HPC recommendation, Dr. Lindberg was concerned that it couldn't be understood without the provision of background context. It was not approved and was sent back to the BDTF. Regarding the BDTF Pacific Research Platform finding, Dr. Peterson felt it only made sense in the context of the previous item. Dr. Gaudi felt the platform was still a work in progress. Dr. Peterson agreed to provide BDTF findings to the NAC as a status report, with Committee concurrence. Dr. Gaudi suggested that the SC provide to the BDTF some feedback on presenting more focused and structured briefings in the future. At the NAC, Dr. Peterson will mention that the BDTF is making good progress.

Regarding a PPS observation regarding investments in planetary protection technology, Dr. Lindberg supported its current format as expressing appreciation for the quick development of the Planetary Protection Technology Definition Team. Dr. Neal recommended that the scientific community also be

involved in the team to help integrate science very early on. Dr. Lindberg felt this was a good addition. The Committee concurred in bringing forward the observation from the SC to the NAC.

The PPS recommendation for an additional FTE in the PPO was approved as a SC recommendation.

Dr. Lindberg recused himself and left the room for the discussion of a PPS recommendation that NASA include an internal assessment of authorization of missions by non-governmental entities to include an assessment by the PPO to determine if the mission meets planetary protection requirements. Dr. Conley underscored the importance of the assessment for treaty compliance. Dr. Amy Kaminski, Executive Secretary of the PPS, added background information on the rationale behind the recommendation, related to Office of Science and Technology Policy (OSTP) and Congressional actions on aspects of space launches carried out by non-governmental entities. Dr. Pieters asked that the recommendation make it clear that it is an international issue in terms of planetary protection policy and requirements. Dr. Avery felt that it was not in the SC's purview to address international vetting, but agreed that NASA has the expertise to determine the planetary protection issues and that the Agency's participation is crucial. The recommendation was approved.

The SC looked at a finding of the PSS Small Bodies Assessment Group (SBAG) on the ARM that was forwarded FYI by the HEOC. Regarding the finding, Dr. Peterson felt the science return was low for the ARM, particularly given the cost. Because ARM is a technology demonstration, NASA shouldn't try to justify it as a science mission. Dr. Jernigan felt ARM was not tied into NASA's message of inspiration. Dr. Neal noted that he disagreed with the SBAG's assessment of the ARM, which he thought to be nebulous and open to interpretation. Dr. Gaudi thought the finding should go through the PSS first, and Dr. Avery agreed that the SC should not act on it. The finding was not passed by the SC. Dr. Neal agreed to put the SBAG finding on the agenda for the next PSS meeting.

Dr. Peterson adjourned at 10:06 am.

Appendix A Attendees

NAC Science Committee Members

Bradley Peterson, Ohio State University, **Chair, Science Committee**
Susan Avery, Woods Hole Oceanographic Institution
Jill Dahlburg, Naval Research Laboratory, Chair, Heliophysics Subcommittee (*via telecon*)
B. Scott Gaudi, Ohio State University, Chair, Astrophysics Subcommittee
Tamara Jernigan, Lawrence Livermore National Laboratory
Robert Lindberg, Jr., University of Virginia, Chair, Planetary Protection Subcommittee
Clive Neal, University of Notre Dame, Planetary Science Subcommittee (*designee*)
Carlé Pieters, Brown University (*via telecon*)
Mark Robinson, Arizona State University
James Marshall Shepherd, University of Georgia, Earth Science Subcommittee (*designee*) (*via telecon*)
Elaine Denning, NASA Headquarters, **Executive Secretary, Science Committee**

NAC Ad Hoc Task Force on STEM Education Members

Anita Krishnamurthi, Afterschool Alliance, **Chair, Ad Hoc Task Force on STEM Education**
Carl Person, Fayetteville State University
Ray Mellado, Great Minds in STEM
Beverly Girten, NASA Headquarters, **Executive Secretary, Ad Hoc Task Force on STEM Education**

NASA Attendees

John Lekki, NASA GRC
Carolyn Mercer, NASA
Geoff Yoder, NASA HQ, SMD Acting Associate Administrator

Non-NASA Attendees

Kenneth Bowersox, **NAC Interim Chair**
Matt Mountain, AURA
Joe Ortiz, Kent State University
Ana Wilson, Ingenicomm, Inc.
Joan Zimmermann, Ingenicomm, Inc.

Telecon/Webex attendees

Mitch Ambrose, AIP
Sara Barber, U.S. House of Representatives
Reta Beebe, New Mexico State University
Linda Billings, NIA
Dwayne Brown, NASA HQ
Laurie Cantillo, NASA HQ
Steven Clark, NASA HQ
Steven Clark, Spaceflight Now
Catharine Conley, NASA HQ, Planetary Protection Officer
Chad Davis, Orbital ATK
Tremayne Days, NASA
John Dyster, Orbital, ATK
Jeffrey Ehmen, NASA
Michael Freilich, NASA HQ
Jeff Foust, Space News

James Green, NASA HQ
David Gump, Deep Space Industries
Charles Holmes, NASA ret.
Grace Hu, Office of Management & Budget
Doug Isbell, NASA JPL
Lindley Johnson, NASA HQ
Amy Kaminski, NASA HQ
Jennifer Kearns, NASA HQ
Mona Kessel, NASA HQ
David Ladler
Michael Liehmon, University of Michigan
Mark Linton, NRL
James Lochner, USRA
George Marino, AGU
Kelly Martin-Rivers, NASA HQ
D. Messier
Michael Meyer, NASA HQ
Michael Moloney, NAS SSB
Marissa Murray, AIP
Doreen Neil, NASA
Benjamin Phillips, NASA
Sean Pitt, SpaceX
Betsy Pugel, NASA HQ
Mark Rails, NASA
Christy Rivera, NASA HQ
Andrea Razzaghi, NASA HQ
Zach Rosenberg, Aerospace Magazine
John Rummel, SETI
Abigail Sheffer, NAS SSB
Robert Shuchman, Michigan Tech Research Institute
Mary Sladek, NASA
Sandra Smalley, NASA HQ
Nick Saab, Lewis-Burke Associates
Thomas Sutliff, NASA
Micheline Tabache, ESA
Robert Taylor, Harris
Anne Verbiscer, BDA
Paula Wamsley, Ball Aerospace
Jim Watzin, NASA HQ
Susan Wirth, Harris
Alexandra Witze, Nature Magazine

Appendix B
NAC Science Committee Membership

Dr. Bradley Peterson, (Chair)
Ohio State University

Dr. Susan Avery
Woods Hole Oceanographic Institution

Dr. Jill Dahlburg
Naval Research Laboratory

Dr. Douglas Duncan
University of Colorado at Boulder

Dr. Bernard Scott Gaudi
The Ohio State University

Dr. James Green
University of Colorado

Dr. Tamara Jernigan
Lawrence Livermore National Laboratory

Dr. Robert Kirshner
Harvard University

Dr. Robert E. Lindberg
University of Virginia

Dr. Janet Luhmann
University of California, Berkeley

Dr. Carlé Pieters
Brown University

Dr. Mark S. Robinson
Arizona State University

Dr. Steve Running
University of Montana

Dr. Walter G. Secada
University of Miami

Dr. David Spergel (*ex officio*)
Princeton University

Ms. Elaine Denning (Executive Secretary)
NASA Headquarters

Appendix C
Presentations

1. Chartering of SMD Division Committees; *Elaine Denning*
2. Juno; *James Green*
3. Planetary Science Division Update; *James Green*
4. Planetary Science Subcommittee Report; *Clive Neal*
5. Planetary Defense Coordination Office; *Lindley Johnson*
6. Planetary Protection Subcommittee Report; *Robert Lindberg*
7. Joint Agency Satellite Division Update; *Sandra Smalley*
8. Harmful Algal Blooms; *John Lekki, Joseph Ortiz, Robert Shuchman*
9. Astrophysics Division Update; *Andrea Razzaghi*
10. Astrophysics Subcommittee Report; *B. Scott Gaudi*
11. Earth Science Division Update; *Michael Freilich*
12. Presentation by SMD Acting Associate Administrator; *Geoff Yoder*
13. "Completing the Census of Exoplanets with WFIRST;" *B. Scott Gaudi*
14. Heliophysics Division Update; *Steve Clarke*
15. Heliophysics Subcommittee Report; *Jill Dahlburg*
16. Big Data Task Force Report; *Charles Holmes*
17. Ad Hoc Task Force on STEM Education; *Anita Krishnamurthi*

Appendix D Agenda



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

NASA Advisory Council Science Committee Meeting July 25-27, 2016

Ohio Aerospace Institute
Industry Room B

Final Agenda (Eastern Daylight Time)

Monday, July 25

1:00 – 1:30	Opening Remarks / Members Introductions / Updates	Ms. Elaine Denning Dr. Bradley Peterson
1:30 – 3:00	Jupiter Orbit Insertion by Juno Spacecraft Planetary Science Division Update Planetary Science Subcommittee Report Planetary Defense Coordination Office	Dr. James Green Dr. Clive Neal Mr. Lindley Johnson
3:00 – 3:20	Planetary Protection Subcommittee Report	Dr. Robert Lindberg
3:20 – 3:30	BREAK	
3:30 – 4:15	Joint Agency Satellite Division	Ms. Sandra Smalley
4:15 – 5:15	Harmful Algal Blooms (HABs)	Dr. John Lekki Dr. Joseph Ortiz Dr. Robert Shuchman
5:15 – 5:30	Discussion	
5:30	ADJOURN	

Tuesday, July 26

8:45	Re-Open Meeting	Ms. Elaine Denning Dr. Bradley Peterson
8:45 – 9:35	Astrophysics Division Update Astrophysics Subcommittee Report	Ms. Andrea Razzaghi Dr. Scott Gaudi
9:35 – 10:15	Earth Science Division Update	Dr. Michael Freilich
10:15 – 10:30	BREAK	



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

10:30 – 11:15	Discussion with SMD Acting Associate Administrator	Mr. Geoffrey L. Yoder
11:15 – 12:00	Discussion	
12:00 – 1:10	LUNCH – Member Research Presentation "Completing the Census of Exoplanets with WFIRST"	Dr. Scott Gaudi
1:10 – 2:00	Heliophysics Division Update Heliophysics Subcommittee Report	Mr. Steve Clarke Dr. Jill Dahlburg
2:00 – 3:00	Big Data Task Force	Dr. Charles Holmes
3:00 – 3:15	BREAK	
3:15 – 4:15	Ad Hoc Task Force on STEM Education	Dr. Anita Krishnamurthi
4:15 – 4:20	Public Comment	
4:20 – 5:15	Joint Discussion SC and STEM Task Force	

Wednesday, July 27

8:30	Re-Open Meeting	Ms. Elaine Denning Dr. Bradley Peterson
8:30 – 10:00	Wrap-Up Discussion	
10:00	ADJOURN SC MEETING	

Dial-In and WebEx Information

For entire meeting July 25-27, 2016

Dial-In (audio): Dial the USA toll-free conference call number 1-888-790-1716 or toll number 1-212-287-1654 and then enter the numeric participant passcode: 4101817. 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 992 934 159, and the password is SC@July2016.

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