

NASA ADVISORY COUNCIL

SCIENCE COMMITTEE

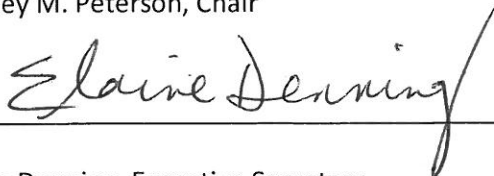
March 10-11, 2016

NASA Headquarters
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MEETING REPORT



Bradley M. Peterson, Chair



Elaine Denning, Executive Secretary

NAC Science Committee Meeting, March 10-11, 2016

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Ingenicomm*

Thursday, March 10

Opening Remarks / Introduction of Members

Science Committee (SC) Executive Secretary Ms. Elaine Denning opened the meeting with a quick review of the Federal Advisory Committee Act (FACA) rules. Dr. Bradley Peterson, Chair of the NASA Advisory Council (NAC) Science Committee called the meeting to order, welcomed members, and did a roll call of meeting participants.

NASA Science Mission Directorate FY17 Budget

Mr. Craig Tupper, NASA Science Mission Directorate (SMD) Director of Resource Management, reported that there is mostly good news for the Directorate in the Fiscal Year 2017 (FY17) President's Budget Request (PBR). Compared to the two previous years, the FY17 PBR is slightly higher and fills a number of gaps. Though funding drops in the notional out-year budgets, Mr. Tupper believes that succeeding years might see even larger budgets.

Among the FY17 program highlights are support to formulate both a Europa mission and the Wide Field InfraRed Space Telescope (WFIRST), with the latter possibly launching as early as 2024. In addition, the PBR accelerates the Landsat-9 mission to FY21, fully funds operations to Mars missions, increases investments in planetary technology, continues efforts to detect and study Near-Earth Objects (NEOs), allocates \$10 million to study a Mars orbiter in the 2020s, increases funding for cubesats, and raises the level of support for the Space Weather Action Plan. A budget feature that has received some attention is \$298 million in mandatory funding. "Mandatory funding" is a function of NASA falling into the discretionary part of the overall Federal budget. Congress specified mandatory categories across the government, and this is more of a bookkeeping feature. It is not a new term for "earmarks," but instead reflects money that must be spent based on existing laws and statutes, as well as Congressional direction. Mr. Tupper presented a chart detailing the success of SMD efforts to provide reliable cost estimates for missions. The total actual cost to develop 13 science missions launched since August 2011, excluding the Curiosity Rover, has come to 1 percent below the original baseline costs. The success of this effort contributes to program stability.

Mr. Tupper next provided budget details by SMD division. In the Astrophysics Division (APD), the FY17 PBR increases SMD Science Education to \$25 million. He noted that SMD Science Education is kept in the APD budget. WFIRST funding is at \$90 million; the Hubble Space Telescope (HST) and the Stratospheric Observatory for Infrared Astronomy (SOFIA) are flat; Spitzer is at the minimum for closeout; and cost growth is covered for the Euclid mission, which is to be conducted with the European Space Agency (ESA). Supporting Research and Technology (SR&T) funds will further the goals of the 2010 Decadal Survey (DS), while directed R&T funds and full-time employee (FTE) funding have been moved to other themes. It is possible that Senior Review funding may be insufficient to continue all currently operating missions. In preparation for the 2020 DS, the APD budget includes \$5 million for studies of four flagship mission concepts. The James Webb Space Telescope (JWST) is currently a separate budget line, but when added in to the overall APD budget, there has been steady funding for the Division and its missions.

In the Planetary Science Division (PSD), the Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) mission launch has been delayed and is under review. PSD is releasing a New Frontiers (NF) Announcement of Opportunity (AO) in January 2017. The Division renamed the Outer Planets program to Outer Planets and Ocean Worlds. Extended missions are funded through FY17, and the multi-directorate Aeroscience Ground Test Capabilities project has been established to sustain Mars entry, descent, and landing (EDL) test capabilities. The PBR includes no adjustments to the budget for InSight, but that will need to be addressed due to the launch delay. The overall PSD budget is around \$1.5 billion, below the FY16 appropriation.

The PBR for the Earth Science Division (ESD) has no significant changes from FY16, though the Sustained Land Imaging (SLI) and Landsat-9 missions are accelerated. Small satellites (smallsats) are a new effort. Similarly, there is nothing significantly new in the Heliophysics Division (HPD) PBR. SMD Science Education is being restructured, and the PBR is lower than that for FY16. Overall, the SMD request is good, as it maintains balance, accelerates Landsat-9, and progresses WFIRST and Europa formulation.

Dr. Douglas Duncan asked the reasoning behind the SMD science education decrease from \$37 million in FY16 to \$25 million in FY17. Mr. Tupper replied that SMD hoped that experience will lead to higher future budgets. In response to a question by Dr. Susan Avery, Mr. Tupper replied that science education covers kindergarten through 12th grade.

Astrophysics Division FY17 Budget and Update

Dr. Paul Hertz, APD Director, summarized Division activities for the SC, beginning with the budget. The FY16 appropriation and the FY17 PBR are both very good, and JWST is fully funded. WFIRST just entered formulation and is well-supported by this budget and the runout. The FY16 appropriation did lead to some unspecified reductions, however, and the FY17 budget also might require some adjustments. APD currently has eight extended missions and three in the prime phase. The Division has increased the AO cadence for small Explorers (SMEXes) and Missions of Opportunity (MOOs). APD is partnering with ESA on that agency's next two large missions, which help APD meet DS priorities. A mid-decade review is going on now, with results expected in May.

The DS recommended Technology Readiness Level (TRL) investments in the middle range, and APD has responded by initiating the competed Strategic Astrophysics Technology (SAT) program. In Research and Analysis (R&A), 100 percent of the 2015 selections were announced within 155 days. The selection rate was 24 percent overall, an improvement over 2014. The Senior Review is ongoing and will report out in May or June.

The Laser Interferometer Space Antenna (LISA) Pathfinder launched in December. This is an ESA technology demonstration with a NASA test package that will go live after the European package is worked through. The Japanese Space Agency (JAXA) Astro-H mission, renamed Hitomi, was launched in February. NASA provided one instrument and some telescope parts for this mission. Testing is going well, spectral resolution is better than the requirements, and no anomalies were found during commissioning. The NASA cycle will begin in late spring.

JWST is proceeding on schedule. All telescope segments have been installed on the backplane, resulting in a complete telescope. The instrument package completed final thermal vacuum testing and will mate to the telescope soon. In addition to Euclid, JWST, and WFIRST, APD missions in development include: the Neutron-star Interior Composition Explorer (NICER), which will launch in March; the Cosmic-Ray Energetics and Mass investigation (CREAM), scheduled to launch in mid-2017; and, the Transiting Exoplanet Survey Satellite (TESS), which is slotted for launch in late summer of 2017.

Dr. Hertz next described the budget in greater detail. The FY16 appropriation comes to \$1.351 billion when adding in JWST. The rest of APD received \$42 million more than the FY16 PBR, but the Division was also subject to directed spending, including \$76 million for WFIRST. As a result, APD must make an adjustment of \$36 million across the rest of the program. The runout for FY17 will allow a 2020s flagship mission launch, and the Division is doing a lot of precursor science in order to make decisions for next DS. The greatest challenge is in the area of operating missions, not including Chandra and HST. The FY16 budget for the APD operating missions is \$62 million, but the FY17 PBR budget for is only \$37 million. On top of that, the next Senior Review will have many new missions to consider. As the JWST launch approaches, its budget line will drop, freeing funds for WFIRST.

APD is starting to prepare for the 2020 DS. Experience has shown that it works better to have APD provide the DS panel with information on potential large missions. Therefore, the Division has stood up some science definition teams (SDTs) on four concepts: a far infrared surveyor; a habitable exoplanet imaging mission; a large UV/optical/infrared surveyor; and an x-ray surveyor. One of these will follow WFIRST, which was the highest priority of the 2010 DS.

WFIRST

Dr. Neil Gehrels, WFIRST Project Scientist at Goddard Space Flight Center (GSFC), reported that WFIRST was just confirmed into Phase A after going through an extensive Key Decision Point-A (KDP-A) management review of the science, hardware, costs, and schedule. The mission received unanimous approval to move forward and has also selected a science team for the next 5 years of formulation. WFIRST was the highest-ranked large space mission in the 2010 Astrophysics DS. The mission's use of the 2.4-meter telescope will enable Hubble-quality imaging over 100 times more sky. The coronagraph will enable imaging of exoplanets to a high degree of contrast. The cost for flying with the coronagraph offset the value of the telescopes donated by the National Reconnaissance Organization (NRO). The telescopes reduce risk for the entire program, and the coronagraph moves the technology forward for direct imaging of exoplanets.

Dr. Gehrels presented a graphic depiction showing the differences between HST and WFIRST. The latter will see 1 million galaxies at a time and will survey 1 billion galaxies over its 6 years of prime mission. This will help determine the acceleration rate of the universe, and help find and identify interesting objects in the universe. Overlap with JWST would enhance both missions. Dr. Gehrels reviewed the science objectives, which include determining the expansion history and mechanisms of the universe, a census of planetary systems in the galaxy, and direct imaging/spectroscopy of exoplanets, among others. He also presented images of the hardware and described their features.

More specifically, in the area of dark energy, WFIRST will be the only observatory doing such comprehensive observations and investigating the acceleration era versus the deceleration era. There will be a baryon acoustic oscillations (BAO) program for supernovae, and the mission will look across the entire redshift range. For exoplanets, WFIRST will identify an unprecedented number of planets, including a large number that are of Earth-mass or less, as well as free floaters and planets that are further out from stars than those exoplanets currently being detected. Finally, the coronagraph concept is to image at high contrast in order to have direct detection and spectroscopy (characterization) of exoplanets. At this point, the team is ahead of schedule.

Mr. Kevin Grady, the GSFC WFIRST Project Manager, listed recent accomplishments and activities. The technology continues making excellent progress and has met all milestones set by NASA Headquarters. The FY17 PBR for WFIRST includes \$90 million from SMD and \$10 million from the Space Technology Mission Directorate (STMD). Augmented funding for FY14-16 enabled significant mission progress. An industry Request for Information (RFI) was issued last July for potential WFIRST participation. Concept study awards have since been released to Ball Aerospace and Lockheed Martin. The WFIRST formulation science working group and science investigation teams were selected in late 2015. Mr. Grady listed key programmatic drivers, such as DS science objectives and recommendations on maturing exoplanet direct imaging technologies. WFIRST will have a 6.25-year mission life. The project website includes many of the technology milestones.

Mr. Grady next provided updated costs for the KDP-A process. Uncertainty in development schedules has narrowed, though the launch date is yet to be determined and it is not yet known which launch vehicles will be available in the 2024-25 timeframe. Design changes came to a verified cost of about \$300 million. At this point, the expectation is for a total cost of \$2.3-2.7 billion in 2015 dollars. Dr. Hertz added that guest

observer and launch costs add up, and some of these remain unknown. The actual changes thus far come to about \$100 million.

Discussion

Dr. James Green had posed some questions about the point spread function, elasticity of the telescope, weak lensing, and temperature of the mirrors, answers to which were addressed in the discussion. The NRO telescopes shifted the issue of the lensing, but it is not the straight trade-off with HST that it sometimes seems. Dr. David Content, WFIRST System Science Manager, explained how the NRO telescopes exceed HST abilities. The coatings will need to be replaced, but this is something that is done all the time at TRL-9. It is not near the critical path and it is not time-consuming. As for the temperature of the mirrors, the range has been identified but not yet decided. Dr. Green asked if the NRO telescopes had been tested. Dr. Content replied that at L2, they will be much more stable than HST. The team is doing simulations and is already working on the stability requirements. In response to a question by Dr. Robert Kirshner about a technology demonstration of the coronagraph, Mr. Grady explained that the instrument will not drive the mission. If the contrast misses, the science team still wants to fly it because it is such a leap forward. Dr. Gehrels added that there is a lot that can be done with a weaker coronagraph. Dr. B Scott Gaudi agreed that a technology demonstration would be beneficial.

Astrophysics Subcommittee Report

Dr. Gaudi, Chair of the Astrophysics Subcommittee (APS), noted that the Subcommittee had not had a meeting since before the last SC meeting. He showed a list of the APS membership, then moved on to explain several science highlights. Among these were the HST measurement of the rotation period of an isolated brown dwarf; the serendipitous discovery of a distant black hole jet; and the strong magnetic fields that the Kepler mission discovered in a majority of stars. The next APS meeting was scheduled for the following week and would focus on gravitational waves, lightweight optics technologies, and large mission science and technology studies.

In addition to submitting concept studies on the four flagship missions listed by Dr. Hertz, APS hoped to deliver to the 2020 DS panel a number of papers analyzing probe missions. These have projected costs that are less than the cap of Medium-class Explorers (MIDEXs) but less than \$1 billion. To study these, the Program Analysis Groups (PAGs) agreed on a joint statement for a Research Opportunities in Space and Earth Science (ROSES) call, which will select roughly 10 proposals for one-year \$100K studies. However, there is concern that the proposed \$100K per study will not be enough to effectively evaluate the probe concepts, so the PAGs recommended that APD spend more on these studies. Dr. Gaudi then presented additional statements made by each of the three PAGs.

Discussion

Dr. Kirshner wondered about the timescale for studying gravitational waves and expressed concern that it was not ambitious enough. He advised thinking about the science priorities. Dr. Hertz explained that NASA and ESA are working on the technology elements now. Meanwhile, APD is following the DS. The Division has done mission concept studies, and the DS can determine the direction from there. Both ESA and NASA have teams to examine options, and it is likely that the two agencies will be partners in a single mission. Dr. John Grunsfeld, SMD Associate Administrator (AA), joined the meeting and commented that the analysis is still not strong enough to identify a direction. Both LISA and the Laser Interferometer Gravitational-Wave Observatory (LIGO) are difficult operations. If NASA were to overinvest early, the Agency might end up with the wrong answer. The gravitational wave discovery is exciting, but it is important to adhere to the scientific process. If the budgets were different, it might be possible to move more quickly, but in all likelihood it would not be possible to develop the technology any faster.

Discussion with SMD Associate Administrator

Dr. Grunsfeld explained the SMD mission, which is to innovate, explore, discover, and inspire. The big science questions ask where we came from, where we are going, and whether we are alone. He was pleased with the FY16 budget appropriation and the FY17 PBR. Heliophysics is now receiving recognition, especially in the area of space weather.

Looking forward a decade to 2026, Dr. Grunsfeld discussed what he expects to see. In addition to the various missions now in development being launched and operating, he believes we will find water in the habitable zones of other planets and will analyze their atmospheres. He expects to begin learning about dark energy and to explore the enormous exoplanet space. The current Mars program fizzles out after 2020, but he expects NASA to operate in a habitable environment with the Mars 2020 Rover and possibly find biosignatures. He expects to see a demonstration of In Situ Resource Utilization (ISRU) and have a sample return mission to Mars. There will be planetary opportunities within our own solar system, asteroid exploration opportunities, and the possible arrival of the exciting future mission to Europa. He likes the exuberance in Congress that helps to enable all of this. In Earth science, the greatest challenge is the changing state of our planet, which we must monitor with spacecraft in order to have the science that policymakers need. Landsat-9 will launch in 2022 as part of this quest. Finally, Dr. Grunsfeld believes that by 2026, heliophysics will have solved the mystery of the solar corona.

Challenges to this future include the need for bold and consistent leadership. NASA also must have continued cost and schedule performance, especially now that routine cost overruns are a thing of the past. High-quality workmanship is an area in which we seem to be slipping, and this affects costs, schedules, and equipment failures. Additional challenges include creating an environment that facilitates teamwork, and promoting science, technology, engineering, and math (STEM) education.

Dr. Duncan noted the comment about workmanship, which relies on having a cadre of high-quality workers. NASA can either accept what is out there or get involved. Dr. Grunsfeld observed that there are many lessons to be learned as experimental scientists. Having science students working alongside engineers, having funded labs with technicians and mentor engineers – this is all critical. We need to make sure we have processes to enable repeatable results. States are no longer funding universities as they once did, and NASA has flat funding.

Dr. Jill Dahlburg noted that laboratories not having funding for technicians also is a problem that needs to be resolved. Dr. Grunsfeld agreed and noted that he learned systems engineering when he was in school when the teachers gave him scientific instruments to fix, and then as a graduate student he was ready to build balloon payloads. However, this is not systematic, and scientists seldom learn how to work in systems engineering these days. Therefore, NASA should partner with engineers to develop science systems engineering. With limited taxpayer dollars, there is a need to formalize survey courses that use real missions. Mission lines such as the Explorers enable this and reinvigorate labs. NASA has 60 years of space systems and lessons learned, so the Agency should be able to do courses with case studies.

Dr. Avery agreed with Dr. Grunsfeld's ideas on large project management and systems integration, and provided an example of an ocean observation project she worked on that was a distributed system rather than a laboratory building. NASA has the experience of building discovery-based, higher risk projects that recognize technological innovation in design, different from a Department of Energy or Department of Defense approach, and should share this with the National Science Foundation (NSF).

In answer to a question by Dr. Robert Lindberg on the planetary protection aspects of daily operations of the Mars Exploration Program, Dr. Grunsfeld said that he wants to answer the question of what, if anything, it will take for Curiosity to approach regions that emerge whether special regions or not. In the daily operations, the spacecraft looks for signatures, and there is a need to identify the points where it helps to

stop and think. On the Magnetospheric Multiscale (MMS) mission, there are scientists “in the loop” who actively serve as co-investigators, review data compared to algorithms, and decide what data to download. This works better than downloading all of the data.

In response to a question by Dr. Mark Robinson on international collaboration, Dr. Grunsfeld spoke of science as being a universal language for those who value facts and rational thought. International participation is not always fast or cheap, but it allows NASA to break boundaries. On the order of two-thirds of the SMD missions have international partnerships. Even when collaborations do not work for given instruments, the partnerships lead to communications and sharing. However, this is why the United States sometimes limits foreign participation by percentage. The costs of delays can be substantial. For example, on InSight, Dr. Grunsfeld hopes the result will be that partners communicate issues sooner in the future. These are definitely lessons learned that could help set communications guidelines for the future. Dr. Carle Pieters asked if it was possible to have transparency given the U.S. International Traffic in Arms Regulations (ITAR); Dr. Grunsfeld answered that international partners have their own equivalents of ITAR, which can complicate collaborations. JWST is allowing NASA to show the national intelligence side of the Federal government what the Agency can do, but ITAR remains a big issue.

Dr. Avery pointed out that for ESD, the House Science Committee has reduced the budget from the PBR for several years in a row. It is a distraction and it is causing both NASA and NSF to lose talent in that field. Dr. Grunsfeld agreed that it is a messy process. However, some of the House cuts are restored when the budget goes into conference with the Senate. He wishes that Congress came to science and asked how to address the issues instead of it being the other way around. In the end, however, Congress comes up with the right answer. Dr. Duncan observed that most people in Congress are unaccustomed to using data for decision-making.

Member Research Presentation – “The Role of the Terrestrial Biosphere in Global Climate and Carbon Cycles”

During lunch, Dr. Steve Running, Chair of the Earth Science Subcommittee (ESS), gave a presentation on terrestrial plant activity and its role in climate change. The variables in calculating factors such as growing terrestrial plant production proved to be endless. Dr. Running gave the example of a La Nina year, showing Earth as a system with evaporation in ocean areas and plant growth increases in arid areas. A longstanding question asks whether we are overconsuming the planet. Crop yields will not keep up with population growth to 2050. There might be a planetary boundary of plant production that cannot be increased by human activities. Another question is whether biomass could be a source of energy. On this question, what the economists predicted was five times larger than what scientists came up with using real numbers, and that was before calculating the value of food versus energy.

Dr. Avery said that when talking about the Earth system, the least understood component is the ocean. The biomass in the ocean is the biggest unknown. Ninety-five percent of the heating goes into the ocean. Dr. Lindberg said that there are advocates of massive irrigation of desert areas, which would change the weather cycle.

Earth Science Division FY17 Budget and Update

Dr. Michael Freilich, ESD Director, explained that the FY17 PBR is balanced and allows ESD to do all of the Earth science it has been doing, informed by the DS and Congressional direction. The Division is trying to get ahead of curve with increases to data systems in anticipation of new missions. ESD is investing now to complete all of its high-priority missions, which will allow the Division to launch these missions during planned dates in the future. The PBR continues and fully funds the Venture-class missions, keeping solicitations and selections on schedule. It also allows limited DS mission studies now and supports the non-flight arena. ESD accounts for 10 percent of the entire NASA budget, which is slightly lower than the

historical proportion. PBRs tend to be close to actual appropriations, and ESD has not had to change its program year by year to adjust to deep fluctuations.

The major strands of ESD efforts are research, flight, applied science, and technology. The Division is trying to advance understanding of Earth as an integrated system, which goes beyond just analyzing data from NASA satellites. An example of the science is tropospheric ozone levels in the western United States. Transported ozone from China offset 43 percent of the expected decrease, and downward ozone from higher in the atmosphere was a factor as well. This all speaks to the fact that Earth science is the study of complex processes.

Dr. Freilich presented a graphic of the Earth-observing research constellation. ESD's portfolio includes missions and instruments on orbit, extended mission, implementation, and preformulation. The PBR funds both the systematic and the competed missions. For the on-orbit missions, he presented the expected end dates based on ESD analysis and the Senior Review. The idea is to measure many elements at the same time in order to tie together the various pieces. The flight budget accounts for about 62 percent of the overall budget. The land imaging program in this budget includes the launch of Landsat-9 in 2021, which is earlier than previously planned. Landsat-10 is notionally the next system. It may change architecturally; ESD will define it in the 2019 timeframe for launch in 2027-28. This progression reflects a holistic program among multiple DSs. The budget continues Venture Class, completes OCO-3 to send to the International Space Station (ISS) in mid-2018, and initiates a smallsat constellation.

Venture Class is a science-driven, cost- and schedule-capped, competed program led by principal investigators (PIs). ESD has done a couple of cycles in each of the three strands – suborbital (EVS), small complete mission (EVM), and instrument (EVI). The third round of EVI selections was just released, supporting a polarimeter instrument and a constellation of 12 cubesats to make frequent measurements of atmospheric qualities in storms. Venture Class constitutes about 12 percent of the total EDS budget. The Division has sought input from the National Academy of Sciences (NAS) DS panel to ascertain whether this is the right balance. Multi-mission operations provide data services, systems, and the production of standard products. ESD is getting ahead of future data needs and has been hosting with international partners in exchange for open data. The Earth Observing System Data and Information System (EOSDIS) budget includes funds for a number of data initiatives.

The ESD R&A program is organized by six thematic, interdisciplinary focus areas that cover all of the major processes and their interactions, in addition to some miscellaneous areas such as airborne science. The distribution in the FY17 PBR pie chart resembles that of the pie chart for the FY15 appropriation. Since the last DS was issued, ESD has increased the flight program's flight time by a factor of three, as recommended. The Applied Science Program has a small budget and a large impact. Finally, the Earth Science Technology Office (ESTO) supports four areas and manages a fifth. ESTO invests at the component and instrument levels, and includes processing approaches both in space and on the ground. The program also started a space-based cubesat validation program.

The last DS was issued in 2007. ESD has made good progress against its recommendations, launching all legacy missions, including relaunched of launch failures. The Division did not receive funds to do all of the recommended new missions but made good progress nonetheless. The next DS is due in 2017. Dr. Freilich reviewed the main 2007 DS recommendations and their status. The Tier 1 missions have all made it at least as far as development, and the Division has begun some Tier 2s and 3s. ESD has picked up some additional responsibilities shifted to NASA from other agencies, such as the National Oceanic and Atmospheric Administration (NOAA).

Discussion

Dr. Lindberg asked how Dr. Freilich would rate NASA on the 2007 DS recommendations, given the budget constraints. Dr. Freilich thought the Agency did great. If one were to count missions recommended versus missions flown, it might appear otherwise. However, there were six legacy missions yet to fly, and NASA flew off all of these, with two launch failures. The recommendations for new missions assumed a 30 percent budget increase over 2 years, which did not happen. However, ESD moved all four of the Tier 1 recommended missions at least through development, did Venture Class, and started work on some Tier 2 and 3 missions. ESD will ask the next DS to rank what remains to be done from the 2007 iteration, specifying what is still important and what is not.

Dr. Robinson asked about the science loss and plan given the loss of the SMAP active portion. Dr. Freilich noted that there are no plans to re-fly the Soil Moisture Active Passive (SMAP) mission. The measurements most affected are the short-term ones that require high resolution. Dr. Freilich described some of the rearrangements made to compensate for SMAP, including looking at use of the L-band on Sentinel 1. The missions ESD flies are important, but early failures are not going to derail others in the queue.

Dr. Avery thought that ESD has done well against the DS, given the issues and constraints. She asked about what is needed in a long-term observing system and how it is progressing. Dr. Freilich replied that it is coming along, and while it is fragile rather than robust, ESD is cobbling it together with considerable help from NASA's international partners. They are moving to an open data exchange, which is helpful. The problem is not the Agency desires, or technology, engineering, or science. It is instead a political/sociological issue endemic in the system. ESD has not yet found a compelling way to describe what is required to demonstrate a new technique, why the science is needed, and how to transfer it to a new long-term system.

Dr. Dahlburg observed that the division between an operational organization and a research organization can be substantial. She gave the example of hurricane detection to illustrate the differences. Dr. Freilich replied that the long-term data agencies have not received the needed funds. Dr. Pieters asked for more detail about the international partnerships. She sensed it was primarily coordination and data sharing. Dr. Freilich confirmed that, adding that there is a need for multiple measurements from multiple missions. This is defined both before and after the spacecraft are developed. Most missions have significant hardware contributions across the spectrum of participation. It runs the gamut, and NASA is open to it all.

Earth Science Subcommittee Report

Dr. Running said that one of the hardest parts of Earth system science is that it requires the endless stitching together of many data streams. Getting a sensor up and pulling down a clean data stream is only the beginning. NASA is the lead in producing global data sets and satellite-based data sets, but the Agency does not lead in Earth system modeling. This raises issue of how to get the final science done.

ESS produced the following findings, which Dr. Running presented to the SC:

- The new international agreement with the EU and ESA for full data sharing from new European satellites is a major step forward.
- The United States Global Change Research Program (USGCRP) Earth System Modeling "Summit" of interagency teams in February 2015 was a positive first step in coordinating model development, global dataset production, and validation activities. This coordinating activity should be continued.
- NASA has an important role in research to improve weather forecasting because of the satellite observational network.
- The 2-step proposal review system has been used in ESD periodically for many years for certain competitions. The ESS finds that giving the program managers the option to use this review system when appropriate retains optimum flexibility.

There were no recommendations associated with these findings. In the area of R&A, Dr. Running pointed out that some ROSES calls have success rates as low as 15 percent. Targeting the calls narrows down the applicants and does a better job of pulling in those who work in the appropriate niche areas. Dr. Peterson said that he recently examined this phenomenon. The only clear data point had to do with resubmission of good proposals that were rejected. Dr. Running ended his presentation by noting that ESS also looked at the Big Data Task Force (BDTF) and the ESD DS.

Heliophysics Division FY17 Budget and Update

Mr. Steven Clarke, HPD Director, began his presentation by discussing the budget. The FY17 PBR for HPD is \$699 million, which he deemed healthy. It supports missions in development, including the Solar Orbiter Collaboration (SOC) partnership with ESA, Solar Probe Plus (SPP), Ionospheric Connection Explorer (ICON), and Global-scale Observations of the Limb and Disk (GOLD), all to be launched in FY18. HPD currently operates 31 spacecraft, almost all of which are in the extended mission phase. OMB provided mandatory spending for HPD in the PBR, included \$10 million additional for cubesats for FY17. HPD manages the cubesat initiative for all of SMD. The PBR also supports the National Space Weather Strategy and Action plan, and increases funding for R&A and sounding rockets. Launch opportunities for cubesats are growing, and HPD is monitoring the level of interest. The PBR includes budget growth in R&A and sounding rockets. The Solar Terrestrial Probe (STP) program will issue an AO in FY17. There was rephasing of the SOC launch vehicle costs, which accounts for some budget fluctuation. HPD's next steps are to grow ROSES competitions and implement the DRIVE (Diversify, Realize, Integrate, Venture, and Educate) program. The draft AO for Explorers and MOOs will be issued imminently; HPD is looking for ways to increase their cadence.

Mr. Clarke next presented the HPD mission chart. MMS is doing very well. The Space Environment Testbeds (SET) flight date has changed to March 2017. As planned, HPD has terminated support for the ESA-led Cluster mission and NASA's Coupled Ion Neutral Dynamic Investigation (CINDI) mission. Among the missions in development, ICON had some issues and concerns that are not expected to affect the launch date. An issue on GOLD is still being investigated but it is expected to be resolved and has not affected the schedule. SPP is also on track for a July 2018 launch date. SOC is an ESA mission, and NASA is concerned about the launch date, as the last design review did not go well.

In January, the Gamma Ray Imager/Polarimeter for Solar flares (GRIPS) balloon mission flew over the continent of Antarctica, however, the flight was somewhat truncated due to weather conditions. However, the data vaults were recovered and the science team was pleased with the flight. The sounding rocket program cadence is aggressive and going well. In the area of space weather, the Subcommittee on Space Weather Operations, Research, and Mitigation (SWORM) was established to follow through on the Space Weather Action Plan. SWORM is creating working groups and developing a reporting process. This subcommittee will coordinate across the Federal government and ensure that progress is being made. NASA is involved in 40 of its 99 actions and leads 16 of them.

The recent total solar eclipse in Indonesia was used as both an outreach activity and a dry run for NASA activities relating to the U.S. eclipse of 2017. The Solar Dynamics Observatory (SDO) just had its sixth anniversary. Thus far, SDO data and science results have appeared in almost 2,500 refereed publications. Dr. Duncan observed that the public interface for SDO is one of the best, as it is easy to use and is a good place to link students.

Heliophysics Subcommittee Report

Dr. Dahlburg explained that the Heliophysics Subcommittee (HPS) is very pleased with both the space weather strategy and the progress made toward the DRIVE initiative. She reported highlights from the recent HPS meeting, at which members heard about SWORM and a campaign to get the community involved. HPS recommended that, for the mandated SWORM funding, the community and HPD investigate

developing a broad program to promote the success of SWORM. The \$10 million augmentation should result in a new program that could lead to mitigation of space weather effects.

A presentation by NASA's Office of Communications (OOC) caused concern about the visibility of heliophysics in NASA public outreach and a corresponding recommendation that HPD take steps to be made more prominent in the OOC campaigns. Dr. Daniel Moses gave a presentation on Payload Adaptor Fittings (PAFs), which the Department of Defense (DOD) and others have used for some time in order to launch secondary missions. As described by Dr. Moses, the potential is very high. An example is the Lunar Crater Observation and Sensing Satellite (LCROSS), which successfully flew as a secondary mission with the Lunar Reconnaissance Orbiter (LRO) in 2009. Mr. Clarke plans to talk to SMD about this issue, and HPS will take it up again at the next meeting.

A presentation by Dr. Jeffrey Newmark on risk tolerance led to an understanding that the issue is the Agency reviews versus the level of the proposed program. PIs can tailor the reviews in the proposal if they can provide a rationale for doing so. Dr. Newmark presented HPS with a fair amount of reading to do on the topic, and the hope is to resume this discussion at the next meeting. In another presentation, Dr. Mona Kessel, HPS Chair, described the top-level ROSES changes for 2016. The Guest Investigator (GI) proposal length will be reduced as an experiment. HPD also canceled the Step-1 review, though the Step-1 proposals will continue to be mandatory in order to guide HPD staff in composing review panels. HPD will also increase the Supporting Research awards to \$200,000. Growing out of this discussion, HPS recommended that HPD assess having a program under DRIVE to support early career researchers.

At the meeting, Dr. Arik Posner provided an assessment of the ROSES 2015 call, for which three call dates are still to be determined. The science centers were of particular interest to HPS, which suggested putting together a "tiger team" to design an implementation plan and timeline. In addition, HPD surveyed some ROSES reviewers. The discussion of this effort sent HPS in the direction of recommending that HPD develop material for, and regularly hold, proposal writing workshops to instruct researchers in the best practices of successful proposals. Workshops of this sort could be useful throughout SMD. Finally, Dr. Jeffrey Hayes discussed the BDTF and told of an extended missions study at NAS that could ultimately allow some flexibility in the scheduling of senior reviews.

Dr. Dahlburg presented two science highlights. First, the Aeronomy of Ice in the Mesosphere (AIM) satellite and the Solar Backscatter Ultraviolet (SBUV) instrument data show that air on the edge of space is getting colder and more humid. Second, it has now been shown that Solar Cycle 25 will have an amplitude similar to that of the current Solar Cycle 24. In answer to a question by Dr. Kirshner on proposal opportunities for early career investigators, Dr. Dahlburg said that HPS just began talking about that and therefore has not had an opportunity to identify or review any relevant data.

Big Data Task Force

Dr. Charles Holmes, BDTF Chair, reported that the Task Force had had one meeting at that point. BDTF encompasses all NASA big data programs, projects, missions, and activities. NASA is still in the process of approving some BDTF members. At the first meeting, those members who had been confirmed heard presentations from SMD program managers, who discussed their big data use and needs. There was also a discussion with NSF representatives.

From 2010-13, NAC had an IT advisory committee. At its last presentation to NAC, Dr. Larry Smarr presented the recommendation that NAC encourage NASA IT and the science committees to collaboratively look at NASA's science structure. NAC then recommended that NASA become more aggressively involved in data infrastructure. There were the partnering opportunities with the Department of Energy (DOE) for a network infrastructure, but few within NASA knew about this. After the IT committee was disbanded in 2013, big data became the responsibility of the SC. Dr. Holmes pointed out that there is concern that as

scientists try to merge the data streams from multiple missions, it will create a computing and data link crisis. There are related concerns that the bandwidth will be inadequate. In the most recent APD Senior Review, the review panelists called out the current infrastructure and technological approaches as almost certainly becoming obsolete at the end of the next review cycle.

Dr. Holmes provided highlights of the sessions at the BDTF meeting. It was reported that in HPD, it is SDO that generates a lot of complex data. Dr. Michael New reported on the Planetary Science Division (PSD) Planetary Data System (PDS) structure; there is great complexity inherent in planetary research. In ESD, EOSDIS serves 9,200 data types spread across a range of topics. Dr. Tsengdar Lee showed the capabilities at the Goddard Space Flight Center (GSFC) and Ames Research Center (ARC). Dr. Fen Zhao then described NSF's data system, which is organized in a series of hubs and spokes for big data. The first phase of the NSF big data initiative will help establish the structure, staffing, and collaborations; the budget is about \$20 million annually for as many as 5 years. The consortia are organized through six institutions, and there are opportunities for NASA to participate on a small scale. BDTF will examine this further at the next meeting.

Dr. Holmes expects BDTF to recommend to the SC and SMD several courses of action intended to improve the science return from NASA's extensive data stores. He does not want to see BDTF reinvent or restudy anything, but rather hopes to see the Task Force break new ground and propose additional ways to identify more science in NASA's data. The draft work plan will have BDTF starting with a survey, followed by nomination and selection of topics, and production of a white paper. The Task Force is funded for only 2 years, and so has plans for four or five more face-to-face meetings, with teleconferences as needed.

As illustrated by examples from HPD, EOSDIS, and JWST, the projected growth of SMD data is substantial. This leads to questions about the Directorate's planning for data infrastructure. NASA should be concerned about forecasts in the semiconductor industry, which no longer discussing increases, possibly signaling that they have reached the limit. Another concern is the use of the term "interoperability," which can lead to inadequate specifications and budget. What the field needs instead are targeted and improved definitions. Data-related activities account for about 5 percent of the SMD budget, and about half of those activities are competed.

Discussion

In answer to a question from Dr. Running on ever-increasing computational capacities, Dr. Holmes said that BDTF is concerned with data storage, computational concerns, bandwidth, and more. Dr. Lindberg asked about media format obsolescence, which Dr. Holmes explained is outside the purview of BDTF. To study it would take additional resources to study the potential use of data that might not be called up. Where it is needed, there are processes to track trends. He was involved in this issue some time ago, and asked for examples of any issues SC members know of or have confronted themselves. Dr. Peterson pointed out that this may include disintegrated tapes. Dr. Holmes noted that format issues should be addressed by current data managers. In discussion, it was pointed out that the Apollo imagery was curated very well.

Dr. Duncan advised Dr. Holmes to talk with industry. For example, the video gaming industry is the group that currently uses the most sophisticated processing, and they have valuable information. Dr. Holmes noted that there are informal channels of industry sources wanting space scientists to do beta testing, including at the NASA centers. Dr. Avery recommended studying failures in order to learn from mistakes. She held that the primary lesson learned is that one size does not fit all.

Public Comment

Ms. Denning asked if any members of the public wished to comment. As no one came forward, discussion among the members resumed.

Discussion

Dr. Peterson led the SC in dealing with recommendations and findings, explaining that findings did not require action but still can be sent up to NAC. He began with the ESS findings. The first read praised the new international agreement with the EU and ESA for full data sharing from new European satellites. It was determined that this wording was incomplete, and Dr. Peterson said that he would pull from the ESS letter to compose something for the NAC. The next finding was also praise, this time of the USGCRP Earth System Modeling Summit of Interagency teams. The finding urged NASA to continue the activity. Dr. Peterson said that he would reword the last sentence to indicate that ESS is pleased to see this development, as the current wording using “should” sounds like a recommendation. The third finding was an observation on NASA’s role in research to improve weather forecasting through the satellite observational network. Dr. Running was advised to take this and the previous finding back to ESS to develop further. The final ESS finding reflected the Subcommittee’s view that ESD program managers should have the option of using the two-step proposal review system when appropriate, in order to retain optimum flexibility. It was agreed to leave this finding as written.

Next were the HPS findings and recommendations. The first recommendation addressed the \$10 million in mandatory funding for SWORM, stating that HPD should try to develop a program that would provide the science research and analysis required for SWORM’s success. Dr. Dahlburg explained that HPS believes that it would be most beneficial if this were to grow into a program and separate line item, as compared with continuing in the LWS line where it is now. She would be happy for the recommendation to stay at the HPS level and Dr. Peterson agreed.

The second HPS finding reflected Subcommittee concerns about the visibility of heliophysics within NASA’s communications campaigns. Dr. Dahlburg mentioned that this was another statement that did not need to be elevated further. Dr. Dahlburg called the SC members’ attention to the possibility of other divisions taking similar action, as much of NASA science is lumped together in the OOC campaigns. It might be helpful to have flags, hashtags, or other signifiers in the campaigns indicating that the funding comes from certain SMD divisions. Dr. Pieters agreed that a lot of the important science is not being shown. Dr. Duncan added that OOC spends a lot of time on branding just with the NASA logo alone, and science should have at least as much attention. Dr. Dahlburg wondered if OOC should provide a briefing to the SC, Dr. Peterson agreed, and Ms. Denning noted that a briefing by OOC would be set up for a future meeting.

The HPS recommendation on creating a new ROSES program element exclusively for early career researchers was also meant to stay at the HPS level, and the SC members agreed not to elevate it. In the ensuing discussion of existing programs, Dr. Lindberg observed that there is a need to articulate that it is important for NASA to cultivate these young investigators for the workforce. He wondered if this should go across SMD. Dr. Pieters agreed, noting that some young scientists go into industry because they cannot get NASA grants. Dr. Dahlburg added that there was a strong impression among HPD staff that supporting demographic data are hard to find. However, Dr. Gaudi mentioned an Astronomy and Astrophysics Advisory Committee (AAAC) report showing that almost all of the hypotheses about proposal acceptance rates were wrong. The main reason for low acceptance rates and the corresponding increase in proposals is resubmission of rejected proposals. When Ms. Denning noted that the NAC is concerned about the proposal process, Dr. Peterson suggested going to Dr. Priscilla Cushman, who led the AAAC team, for a follow-up briefing. SC might also seek NAC advice on what might be done next, though this issue might best be raised at the July NAC meeting.

The HPS finding on an implementation plan and timeline for the Heliophysics Science Centers (HSCs) called for in the DRIVE initiative boiled down to a need for specificity. The recommended tiger teams would provide a direction and stop the speculation. Dr. Peterson advised recrafting this into both a finding

and a recommendation, but Dr. Dahlburg was reluctant to do so without consulting HPS. Dr. Peterson asked her to raise the issue at the next HPS meeting.

HPS also generated a recommendation that HPD develop and conduct proposal writing workshops to instruct researchers in the best practices of successful proposals. Dr. Dahlburg explained that this did not reflect the quality of current proposals, but rather was something that could be useful and might help the reviewers. For example, the workshops might identify key words that reviewers scan for when reading proposals. Dr. Peterson thought this could be targeted at early career researchers as well, and said that this text should be integrated into the new ROSES program element recommendation. He planned to add it to his letter to the NAC as a comment.

ADJOURN

The meeting adjourned for the day at 4:40 p.m.

Friday, March 11

Re-Open Meeting

Ms. Denning opened the second day of the Science Committee meeting. Dr. Peterson turned the meeting over to Dr. Lindberg, the first speaker.

Planetary Protection Subcommittee Report

Dr. Lindberg, Chair of the Planetary Protection Subcommittee (PPS), reported that the Subcommittee last met in early December of 2015. Their focus was on Mars, current operations, and future plans.

News about the continuing study of Recurring Slope Lineae (RSLs) is that there is now convincing evidence that they result from the flow of liquid water on Mars. The question is whether there are RSLs at Gale Crater, where the Curiosity Rover is operating. Two dark streaks at Gale Crater are candidate RSLs, but they are not yet confirmed. It will be necessary to observe the seasonal cycles first. In the meantime, Curiosity is keeping a distance.

PPS also received a briefing on engineering progress toward collection and caching plans for Mars 2020. The briefing described the sampling methodology, in which samples will be collected in tubes. Those samples will probably sit on the Mars surface for roughly a decade before they can be collected and returned. They may be stored on a Rover temporarily, but the strategy is to leave them in one to three caches on the surface. The total sample size for all tubes together will be about 500 grams. Each tube is roughly the size of a test tube and the samples the size of a piece of chalk. The capability will exist to collect more, then down-select, but that will depend on the design of the return mission.

There will be “witness samples” of empty tubes, which are still in development. From a planetary protection standpoint, the requirement, for the Category IVb outbound mission is to assure that the returned samples do not contain Earth biological or organic contamination, for which there are two options: 1) go through a microbial sterilization of the entire spacecraft; or, 2) sterilize the subsystem. Both of these strategies have been employed on prior missions, and the second option is more likely to be chosen due to cost considerations. The potential issue is in defining the subsystem. The program’s approach is to declare that the subsystem is the sample tube. The challenge is demonstrating that the rest of the spacecraft, which is cleaned to lesser Category IVa requirements, does not indirectly contaminate the samples.

All Mars missions must be cleaned to the IVa standard in order to prevent forward-contamination. The IVb standard applies to missions looking for extant life, and IVc is cleaned to Viking levels, where the mission visits special regions. In this case, the subsystem would be cleaned to IVb and the remainder of the

spacecraft would be cleaned to IVa. This sample collection design implementation and cleanliness approach is not yet final, and it is an area of concern to the PPS.

The PPS made the following recommendations:

- The Subcommittee heard summary briefings on two reports generated at the recent Committee on Space Research (COSPAR) Colloquium on Mars Special Regions and Icy Moons. The purpose of the colloquium was two-fold: to prepare an update to the COSPAR Bureau and Council on the COSPAR Planetary Protection Policy for Mars Special Regions, and to provide input for a position paper on planetary protection requirements for sample return from icy bodies. The recommendations from the two colloquium reports will be formally addressed during the 41st COSPAR Scientific Assembly to be held in Istanbul from 30 July-7 August 2016. Based on the sound merit of the recommendations and their anticipated adoption by COSPAR, the Subcommittee recommends that NASA's Office of Planetary Protection (OPP) embrace these new recommendations immediately.
- In order to ensure that future scientific instruments can meet the challenges of planetary protection implementations for missions to worlds that could support Earth life, the Subcommittee recommends that NASA provide support to enable instrument developers to qualify and employ construction methods that will be compatible with the use of system-level dry heat microbial reduction (DHMR) over the appropriate time/temperature range. Concomitantly, the Subcommittee recommends that NASA benchmark or consider engaging the Space Science Board (SSB) to conduct a study to identify successful approaches by which modern instruments can be subjected to the current suite of commercially available microbial-reduction methods, including the use of DHMR. Approaches from other fields (including medical, military, and food-industry practitioners) would be particularly important to evaluate. Methods identified for use should be compatible with implementation strategies capable of complying with the regulatory framework for planetary protection currently in use by NASA and COSPAR.

Dr. Lindberg said that, in regard to the second recommendation, NASA needs to be able to have instruments that can be cleaned to go to special regions. However, the technologies have not been advanced to that level. Dr. Catherine Conley, head of NASA's Planetary Protection Office (PPO), said that Russia used gamma radiation, which ESA will share with NASA. Dr. Robinson asked what is known about the survival of organisms in deep space. Dr. Lindberg replied that there has been much work done on that, and there are extremophiles that can survive. Some live as spores in the temperatures that would be present in the Mars sample return mission. Dr. Conley added that this work has been going on for decades now. Some has been done on ISS. Dr. Lindberg added that part of the question is survival, and part is whether there might be contamination of the sample with organics.

PPS also forwarded a finding that read:

- The Subcommittee heard from SMD Associate Administrator, Dr. Grunsfeld, and was exceptionally pleased to hear both his full commitment to the NASA planetary protection activity, which he leads as described in NPD 8020.7G, and the knowledge and insights that he brings to that role. We support Dr. Grunsfeld's recent guidance to the Mars Exploration Program, the Curiosity Science Operations Working Group, the MSL Science Team, and the Planetary Protection Officer on the immediate need for a process to incorporate planetary protection considerations in daily surface operations as well as the need to develop a plan of action for encountering any potential Special Regions. We also support Dr. Grunsfeld's plan to convene a workshop on the potential for finding Special Regions within Gale Crater.

PPS made the following observation:

- A major focus of the December 8-9th Planetary Protection Subcommittee meeting was the planetary protection implementation strategy for the Mars 2020 Project, particularly with respect to the Mars

2020 sample caching system (SCS). The Subcommittee was impressed with the detailed presentations provided by JPL and the Mars 2020 team on the SCS design. The Subcommittee also appreciated the detailed presentation by JPL on the current status of the SCS implementation as part of the overall mission planetary protection implementation (which was not presented). The Subcommittee makes the following observations:

- Current Mars 2020 Project plans are now closer, both theoretically and practically, to the planetary protection requirements given in NPR 8020.12D for a subsystem level planetary protection implementation of a Category V, restricted Earth return, mission;
- No technical showstoppers appear to be present that should prevent the Mars 2020 Project from implementing a successful planetary protection strategy. However, many details remain unresolved, and the overall plans, schedule, and costs for the planetary protection implementation were not presented;
- Although Mars 2020 has been creative in pursuing new approaches to planetary protection implementation and adapting new concepts based on the nature of science anticipated, it remains the responsibility of the Mars 2020 Project to demonstrate that their approach meets the current, published planetary protection requirements;
- Consistent with NASA policy, if the Mars 2020 Project cannot meet the stated requirements then it will need to seek a waiver for implementation strategies that still comply with overall planetary protection objectives, while maintaining design options for their implementation in case such a waiver is denied; and
- Continued active engagement with the Planetary Protection Office will be critical to the Mars 2020 Project's success in planetary protection implementation.

Next, Dr. Lindberg presented the status of three open recommendations from 2015. The recommendation that the NASA internal review of proposed licenses for launches and reentries by non-governmental entities include an assessment by SMD and the PPO has been addressed. A recommendation to declare the Mars 2020 mission a Category V mission was tabled by the NAC, as was a recommendation concerning the Planetary Protection Contingency Action Plan for ongoing surface operations. For the latter recommendation, Dr. Grunsfeld has recently taken action consistent with the recommendation.

Dr. Peterson asked that if methane is detected, is there any process except to leave the area. Dr. Lindberg explained that detection of methane alone would not lead to designation of a special region, but a source of methane would be a special region. In response to a question by Dr. Dahlburg, Dr. Lindberg noted that launching to low-Earth orbit (LEO) is not a cause for concern, but visiting other bodies is. Dr. Janet Luhmann, PSS Chair, pointed out that there is an inherent conflict in that NASA intends to find life and yet does not want to contaminate an area. This has brought up suggestions to designate exploration zones. She wondered if this might be feasible and if NASA feels sufficiently confident to do this. Dr. Lindberg said that this has not been discussed at the COSPAR level. However, if a spacecraft is cleaned to IVc, it can go to special regions. Special regions must be protected from forward-contamination, but they are not off limits. He does not want to confuse exploration with forward-contamination.

Planetary Science Division FY17 Budget and Update

Dr. James Green, Director of NASA's PSD, provided an update on Division activities. Many PSD missions are conducted in conjunction with international partners. As noted earlier in the meeting, NASA postponed the launch of InSight from 2016 to 2018. Plans are to down-select a Discovery mission later this year.

Congressional support for PSD is quite high. The FY16 appropriation is \$1.63 billion, \$270 million above the FY16 PBR. The Division now has healthy budgets in each area. Congress is especially interested in outer planets research and funded PSD to move Europa into Phase A. This funding includes a lander. PSD was also directed to do a joint study with ESA on Asteroid Impact & Deflection Assessment (AIDA)/Double Asteroid Redirection Test (DART). Congress further directed PSD to establish a new

Ocean Worlds program with a primary goal of discovering extant life on another world. Therefore, the funding line was changed from “Outer Planets” to “Outer Planets and Ocean Worlds.” Congressional appropriators directed PSD to use a mix of Discovery, New Frontiers (NF), and flagship missions in this program. Dr. Robinson asked if this meant that ocean worlds-themed Discovery missions will have a higher priority in selections. Dr. Green replied that a competition is a competition. Europa is the flagship that will address this, but a competition selects the best mission available.

The PBRs for FY17 and FY18 are lower than the FY16 appropriation, though the notional out-year budgets eventually grow. The Discovery program is going quite well. The Discovery AO brought in 28 proposals. PSD selected five Phase A studies: two missions to Venus, an Earth orbiter to characterize NEOs, a survey of asteroids, and a deep space optical “journey to a metal world.” The Division is partnering with STMD on a number of projects, including the Deep Space Optical Communications (DSOC) that would be demonstrated on several of the five missions, as well as an advanced solar array.

Dr. Green showed the status of three NF missions: New Horizons, which had its Pluto flyby in July 2015; Juno, which will arrive at Jupiter in mid-2016; and the Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer (OSIRIS-REx), which has a launch window in early September 2016. The next NF AO is in process. The DS defined five major strategy areas for NF; as noted Congress recently directed PSD to add Ocean Worlds (Titan and Enceladus) to this list. In response to a question from Dr. Pieters, Dr. Green clarified that while Ocean Worlds did not go through the DS process, the Planetary DS was issued in 2010, which was before the pertinent discoveries were made. There is a very strong science case for Ocean Worlds to be included among the NF strategy areas, and the NF program is supposed to be adaptable to new discoveries. Dr. Green made the point that the DS is not supposed to be followed blindly where circumstances dictate a change in strategy. PSD presented this to PSS, will present the decision and rationale to the NAS Committee on Astrobiology and Planetary Science (CAPS), and plans to seek community feedback via the AO process. Dr. Pieters observed that NF is already oversubscribed, which is discouraging. Dr. Green replied that PSD has external elements it must accommodate. The Division received both Congressional direction and substantial specific funding for Ocean Worlds research, and he must respond to Congress. This was a big discussion in the recent PSS meeting, and there is a recommendation about it.

For the Mars exploration program, PSD has received good funding. The next orbiter is under study, and the Division has \$10 million with which to identify the next mission beyond Mars 2020. The Europa multi-flyby concept is doing well; it is in Phase A lander concept studies. PSD has a standard sequence of events when exploring a planet: flyby, orbit, land, rove, and return samples. An orbit of Europa would be difficult, however. PSD will try to borrow from the success of the Cassini mission. Unfortunately, the funding did not take into the mechanics or the science needed for success.

In the Small, Innovative Missions for Planetary Exploration (SIMPLEx) program, PSD selected two cubesats, which are difficult to use in planetary science. However, with the communications infrastructure in place at Mars, they might be feasible there. The program selected several other missions for Phase A. An unfunded Congressional mandate for the Planetary Defense Coordination Office (PDCO) is to identify 90 percent of the 140+ meter asteroids. PSD is working with ESA, the Federal Emergency Management Agency (FEMA), and others on this effort. Dr. Robinson asked about the goals and objectives from Congress for Europa. Dr. Green explained that Europa is a strategic mission despite the huge radiation environment. Landers could survive 2 weeks or more under the current schematic. The landing could occur to enter the most benign radiation areas, and the landers would “hide” in those areas.

Planetary Science Subcommittee Report

Dr. Luhmann began her presentation by noting that PSS met the same week as the SC, overlapping by a day. She shared excerpts from the finding regarding Ocean Worlds. There is the need to follow the DS, so

adding Ocean Worlds to the NF program resulted in some consternation. This new element was not vetted and seemed to have a political edge, among other things. The finding is as follows:

- We applaud the public and legislative interest in Ocean Worlds spurred by recent discoveries related to the possibility of extant life in the oceans of Europa, Enceladus, and Titan. The increased resources made available to PSD significantly enhance future efforts to explore these intriguing environments. To maximize the scientific return of the Ocean Worlds initiative, we support NASA's science community-based road-mapping activities, including the Outer Planets Assessment Group (OPAG) "Roadmaps to Ocean Worlds" (ROW). The ROW report is expected by December 2016 and will provide input for the mid-term Decadal assessment. PSS encourages PSD to put in place as soon as possible a process to integrate the community input on science objectives and obtain subsequent confirmation that implementation concepts exist that can achieve those objectives within the New Frontiers cost cap. The PSS encourages PSD to ask the National Academies Committee on Astrobiology and Planetary Science (CAPS) to consider whether inclusion of Ocean Worlds in NF-4 can be done via the processes and practices available, and to identify a path for taking advantage of similar exciting opportunities of this nature going forward.

Dr. Luhmann noted that Titan and Enceladus are targets that Congress designated, but OPAG is looking at all candidates. PSS is encouraging PSD to obtain community input and consider whether the NF cost cap can accommodate the additional missions. This is the rational approach to what PSS members all saw as an exciting opportunity. However, the timescale is short and there is a lot to do. It calls to mind how one changes the DS in response to new opportunities. Dr. Pieters pointed out that the DS process goes through a prioritization, a detailed discussion. She was not sure how this can be easily incorporated. Dr. Luhmann replied that this is at the heart of the community discussion. The net is positive, in that there is now high Congressional interest in a rich area of planetary science.

PSS also had a finding in regard to the Europa lander. The concern is that it might have an impact on the multiple flyby mission, which the community does not want to see delayed. The finding reads as follows:

- PSS applauds the strong backing for a Europa mission and supports the goal to launch no later than 2022 to enable arrival of a spacecraft at Europa as early as 2025. We applaud the progress made with instrument selection, accommodation, and mission formulation for the multiple flyby mission. The PSS encourages the plan to carry the lander in a separate, independent spacecraft, which minimizes risk of delaying arrival at Europa, and for the Europa Lander Science Definition Team to report on how science goals in the decadal survey will be met by the Europa Lander.

Another finding addressed the R&A reorganization, which has been controversial, though there were fewer issues this time:

- The PSS recognizes the amount of effort required to compile information on PSD program elements in the reorganized R&A program and appreciates the thorough summary on funding level by planetary body provided. We applaud the development of key word tools that will allow assessment of programmatic balance in future years. Where we continue to be concerned is that the selection rates (average of ~21%) mean that an investigator can receive routinely high scores at Very Good (4.0) or Very Good/Excellent (4.5) and still not be selected for funding. The PSS encourages NASA to continue to work to increase the level of funding for R&A programs.

Dr. Peterson noted that the selection rate issue will be discussed at the next SC meeting, when there will be an AAAC presentation.

Another finding was:

- Laboratory instruments and facilities are critical for Planetary Science. The community perceives that PSD R&A reorganization resulted in underfunding of a significant proportion of these resources to the point at which the science they support is put at risk. PSD is concurrently assessing

the need for facilities rather than individual PI labs and research teams. The PSS will obtain community input, through the AGs and other avenues as appropriate to inform discussions with PSD about the challenge and help formulate potential solutions.

Dr. Dahlburg recounted Dr. Grunsfeld's discussion of the need for labs to have technicians, noting that he suggested working with engineers to develop science systems engineering programs in order to reduce mistakes.

PSS considered a finding about sample return, but decided it was premature pending further study. The Subcommittee members had also heard anecdotal information that the Deep Space Navigation (DSN) transmissions are losing increasing amounts of data, but again would like to have some study of this, and that is in the finding. Funding cuts to DSN are a related issue. Dr. Green said that the Division would like to solve this internally if possible and has begun those discussions. Regarding the next finding, Dr. Luhmann said that PSS also is concerned about funding of the Arecibo Observatory, which is an important resource. NSF is cutting back on its funding and is seeking other partners. Finally, PSS issued two statements as findings: one welcoming the creation of PDCO and another that PSD should continue its foreign mission participation.

Among the planetary science nuggets were the discovery of methane snow on Pluto's mountain peaks, an image from the Dawn mission's orbit around Ceres, the formation of chondrules during planet formation, and the Mars exploration successes. In answer to a question by Dr. Robinson, Dr. Green said that the Europa launch is being studied; the trade is time, and this is early in the process.

Nexus for Exoplanet System Science (NExSS)

Dr. Mary Voytek of PSD described this cross-division effort, based on the concept of maximizing research through coordination. Exoplanet research cuts across all of SMD, and NExSS is meant to leverage programs and break down barriers by enabling communications. The program relies on a virtual coordination network that supports investigators in this area. NExSS has already provided opportunities to share information and ideas, support community standards, encourage innovation, and promote ways of moving forward. Although ESD is not yet involved, the group is working on bringing the Division on board.

Measures of success include such things as influencing the upcoming PSD and APD Decadal Surveys, spawning ideas for new missions, and more. Dr. Voytek described the selection and composition of each team, along with their focus areas, such as habitability. The teams began meeting in 2015 and now have monthly webinars and PI teleconferences, along with a website and mailing list. The effort has already generated a white paper, *Laboratory Work for Understanding Exoplanet Atmospheres*. The paper was led by Dr. J. Fortney and had more than 30 authors, 10 of whom are NExSS team members. It identified future measurement needs, which will feed into ROSES calls. It also advised three workshops, the first of which has been held in conjunction with NSF and addressed features in spectra that help determine habitability. NSF is a potential partner.

Next will be a biosignatures workshop in Seattle, to be held in July and jointly led by PSD and APD. This fall, a workshop related to heliophysics will focus on exoplanetary space weather, climate, and habitability in order to identify the stars that are best to search for habitable planets and life. A face-to-face meeting in May will be broadcast on NASA TV. Social media efforts have benefitted from the assistance of a former Washington Post science reporter. In response to a question by Dr. Dahlburg, Dr. Voytek noted that PSD has budgeted \$250,000 for the NExSS coordination, leads, workshops, website, and science reporter. The proposal costs came from existing calls, and Congress is interested in these activities.

Space Communications and Navigation (SCaN)

Mr. Badri Younes, Deputy Associate Administrator for Space Communications and Navigation within NASA's Human Exploration and Operations Mission Directorate, discussed NASA's Space Communications and Navigation (SCaN) Program. Science at NASA is highly dependent on SCaN, because without communications, much of the science would not be possible. However, SCaN seems to come to people's attention only when something goes wrong. Not every problem with SCaN is due to the budget. The budget is challenging, but that is a fact of life. SCaN performance has been 99.7 percent, exceeding the 95 percent requirement, especially on high-priority missions. The Program has overall responsibility for all of NASA's space communications, as well as navigation policy. SCaN interacts with the U.S. Air Force (USAF) and negotiates with international bodies as well.

Mr. Younes described the Program's operations, which rely on worldwide networks, and commercial and partner assets in addition to the facilities that NASA owns. Among the 20 stations are three for the Deep Space Network (DSN), 15 for the Near Earth Network (NEN), and 3 for the Space Network (SN). SCaN provides communication for over 100 missions daily, downloading thousands of billions of bytes in a volume equivalent to the entire content of the Library of Congress. Plans are to move to even higher data rates to accommodate NASA's science and exploration mission. SCaN resisted the effort at NASA and elsewhere to terminate Voyager, which continues moving further and is still powered. SCaN will maintain this support for as long as Voyager can communicate. The program will attempt to recover communications with the Solar TERrestrial RELations Observatory (STEREO) B in April through an experimental technology.

Mr. Younes next discussed activities at the DSN. In response to a question by Dr. Running, Mr. Younes noted that NASA funding is stable for the Canberra Deep Space Communications Complex (CDSCC) and does not threaten operations there. Dr. Lindberg noted that some PPS members visited Madrid and had a tour of the Madrid Deep Space Communications Complex (MDSCC), and that it seemed the 70-meter dish was to be retired. Mr. Younes clarified that there has yet to be a decision regarding the possible retirement of MDSCC equipment. Different antennas support different bands, and it may be that the 70-meter antenna will be repurposed for radio astronomy and NEO tracking. There is one 70-meter antenna at each DSN site. SCaN is expanding capacity for the MDSCC and CDSCC antennas, the latter being important because communications from the southern hemisphere is required for some missions.

Next, Mr. Younes presented the schedule for the DSN Aperture Enhancement Project (DAEP). These structures can operate in winds up to 60 mph, with stowage of antennas being an option in the face of higher winds. SCaN is working off of a phased schedule of 10 years for the expansion. The risks are manageable and the Program has redundancy. The network operates three shifts per day and each site follows the sun for 9 hours daily. SMD is extending so many missions that it is increasing the SCaN load during a period that the Program's funds have decreased. SCaN continues to develop partnerships in order to increase capacity.

In response to a question by Dr. Running, Mr. Younes answered that DoD has contributed funds to the Tracking and Data Relay Satellites (TDRS). The next launch is in mid-2017, but funds for launches are tight. The TDRS system requires six active satellites and one on-orbit spare; right now, there are six and two spares, one of which is at the end of its life and is used for testing. These satellites are aging, with the oldest about 25 years. NASA has done many amazing things through TDRS, and nothing in the commercial sector equals its performance. Given SCaN's budget, program managers decided to limit investments to transformational technology. Mr. Younes listed some examples of these investments, such as the deep space atomic clock (DSAC). Deep Space Optical Communication (DSOC) is another area in which many recent breakthroughs have occurred. The Laser Communication Relay Demonstration (LCRD) mission, a joint partnership with the Space Technology Mission Directorate, is scheduled to launch in 2019.

In answer to a question about ka-band communications from Dr. Robinson, Mr. Younes stated that all of the stations are ka-band capable. SCA_N is adding forward direction to some. Dr. Peterson noted that the astrophysics missions planned at L2 (WFIRST, JWST) will transmit an enormous amount of data. Mr. Younes answered that SCA_N is looking at how to address this fact. For JWST, SCA_N will be able to use current equipment, but the Program will need a hybrid solution for WFIRST. His team is already working with the WFIRST mission manager. As for the community perception of a problem, every mission has its problems; SCA_N manages its issues. When mission data are not captured, it is very rare that the problem is with the ground equipment. More often, the issue stems from either the mission or weather.

Discussion and Wrap-Up

Dr. Peterson began the review of recommendations and findings by starting with PPS. The first recommendation noted the COSPAR colloquium recommendations. This was meant to support Dr. Conley's office, according to Dr. Lindberg, who noted that implementation of these recommendations only after the COSPAR summer meeting might make compliance by the Mars program office more difficult. Thus, it would be prudent to adopt it now. ESA has adopted this resolution. It is also relevant to planning for Ocean Worlds. Dr. Peterson said that it would be provided to the NAC FYI and not for action.

Next was a PPS recommendation that NASA support developers in devising instruments that can be cleaned via DHMR, while also engaging the SSB to identify approaches by which instruments can be subjected to currently available microbial-reduction methods, including DHMR. Dr. Lindberg said that the sense of PPS was that if NASA is serious about Mars exploration, the Agency needs to be able to have instruments that can be cleaned enough to go to special regions. However, NASA has not advanced the technologies to that level. In response to a question by Dr. Pieters, Dr. Lindberg noted that the cost estimates from NASA and ESA are consistent in this area: the cost of IVc sterilization is equivalent to the cost of one instrument, or about \$70 million. The concept of discussing the issue with representatives of other industries that have been sterilizing for a long time came from PPS. Dr. Peterson suggested sending this to NAC as informal advice, as they may want more complete info on the impacts. Dr. Lindberg noted that it goes beyond SMD to the Human Exploration and Operations Mission Directorate (HEOMD). NASA cannot do human exploration or go to special regions without this. Dr. Peterson said he would take it to NAC.

In discussion, Dr. Robinson asked about extremophiles. Dr. Lindberg explained that it is an imperfect process, in that it is not possible to prove their existence in this scenario without the mission. The absence of proof is what exists. Dr. Conley added that over-exposure experiments have shown some survival of organisms that cannot even be identified.

PPS also submitted a finding praising Dr. Grunsfeld's commitment and efforts in this area. Dr. Peterson said that this was a simple finding that would go into the SC letter and no action was needed.

Finally, PPS submitted an observation having to do with the unresolved planetary protection elements of the Mars 2020 project. Dr. Lindberg explained that all too often, cost is used as a reason to not follow policy. In this case, the policy has not changed. Dr. Peterson observed that the Mars 2020 team is characterizing the issue as the level of sterility of the sample vessels. Dr. Lindberg stated that this is a creative definition of a subsystem, proffered in order to meet their own needs, and he challenged them on this. This proposed definition of subsystem allows a dirty Rover with a dirty arm, with a clean test tube. It results in many opportunities to contaminate the sample in the process. Dr. Robinson pointed out that the observation does not say that, and Dr. Green of the SC agreed, stating that it should be more straightforward. Dr. Robinson went on to say that PPS should state what is wrong so that the Mars team can correct it. While PPS is trying to avoid being prescriptive here, they do not articulate the problem – they are too polite and positive.

Dr. Peterson said that the Subcommittee must remain objective and positive, in that they recognize that NASA is trying to solve the problem. Dr. Luhmann added that this has been discussed for many years. SC

Member Dr. Green said that it should be as simple as “we don’t believe you’re in compliance and you should come into compliance.” Dr. Lindberg explained that there would be push-back, which would take him back to the Subcommittee. He wanted this to be in the SC meeting record, then maybe have PPS develop something for the next SC meeting. It might be appropriate to have a joint observation from PPS and PSS. Dr. Luhmann agreed. Dr. Peterson said that there must be a way to adjudicate an ongoing dispute, as in whether the redefinition of “subsystem” violates the regulations. He decided to have an off-line discussion with Dr. Grunsfeld on how to resolve this issue.

Moving on to the PSS findings, of which there were nine, Dr. Luhmann said that they were all for PSD and were still being crafted due to the timing of the recent meeting. The first finding discussed was on Ocean Worlds, at the Chair noted that PSD’s Dr. Green had addressed the caps. The SC then reviewed the Europa lander finding, which applauds the strong backing the mission has received. In discussion, Dr. Lindberg pointed out that NASA has always adhered to an ordered process, as PSD’s Dr. Green described, and this has the lander on the surface without information having been previously obtained from an orbiter. Dr. Peterson said that the mission architecture included a survey before landing.

Dr. Luhmann said that the findings on the R&A reorganization, on which there was a friendly conversation at PSS, and the laboratory facilities, which will have a data gathering phase, did not need to go to a higher level. Regarding the next finding, sample return is coming along, and there has been a lot of effort by the international community to think ahead in this area. NASA and PSD should take advantage of this.

In regard to the DSN finding, Dr. Luhmann explained that all of the PSS information was anecdotal. Therefore, the Subcommittee was asking SMD to determine if there really is a problem. The PSD Director does not believe there is one, and Mr. Younes said that there have only been a few issues, a portion of which have been related to the spacecraft, rather than the communications network. It was pointed out that the SCA_N download efficiency exceeds 99 percent, far exceeding the Agency’s requirement of 95 percent, and Dr. Lindberg observed that the SC had heard two different things. Since the PSS information is anecdotal, it might be useful to have a briefing with quantitative data. Dr. Luhmann advised against recommending a new effort. She did not think there was a point to anyone developing a briefing or documentation. Dr. Peterson suggested that in that case, there was nothing to take forward. Dr. Holmes explained that during his time at NASA, he was responsible for the interface to the DSN from SMD. He offered to check on this informally if needed. Dr. Peterson thanked him, stating that for BD_{TF}, Dr. Holmes’s offer would be appropriate. He asked Dr. Holmes to report back, and asked Dr. Luhmann to ask PSS members to bring forward concrete examples. He then stated that SC was ending discussion on this finding.

Next, Dr. Luhmann explained that PSD helps support the Arecibo facility but cannot fund the expenses that NSF has carried. The finding notes the open problem of finding a new partner. It is not clear what actions are possible. Arecibo supports important work and is very valuable, and the cost of dismantling it is huge. NSF is divesting itself of older facilities and has decreased its investment. Dr. Holmes pointed out that this could affect upcoming missions and NEO detection. Dr. Peterson said that he would remove the action verbs and pass it on to the NAC as information.

Dr. Luhmann said that the PDCO finding was primarily an observation acknowledging the founding of the office. Lastly, the foreign mission participation finding reiterates encouragement to continue collaborating. The comment on State Department restrictions simply covers the bases. In discussion, in the last sentence the word “given” was changed to “within.”

Dr. Duncan raised the issue of NASA education support. He noted that Dr. Grunsfeld reported that there will be a 30 percent budget cut in this area, and that NASA would see what works, then ramp back up. However, NASA has been doing education for 15 to 20 years and already knows what works. If there is a

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budget cut of 30 percent, therefore, programs that work are cut by 30 percent. He thought that this was unwise. Dr. Peterson said that the Committee would request a more focused discussion on that at the next meeting.

Ms. Denning explained that many of these findings and recommendations would go into the SC Chair's letter to the NAC Chair as FYI items, and that some findings may be chosen for the NAC presentation, and Dr. Peterson concurred.

Dr. Lindberg said that Dr. Green of PSD supports a joint meeting of PSS and PPS, which will be set up for the summer. Dr. Running observed that there was a great deal of variability in the subcommittee reports in terms of the level of detail. He would welcome instructions or a template, along with advice on the level of detail and the types of issues to bring forward, and Ms. Denning agreed to do that.

ADJOURN

The meeting was adjourned at 12:22 p.m.

Appendix A
Attendees

NAC Science Committee Members

Bradley Peterson, Ohio State University, *Chair*
Susan Avery, Woods Hole Oceanographic Institute
Jill Dahlburg, Naval Research Laboratory, Chair, Heliophysics Subcommittee
Douglas Duncan, University of Colorado
Scott Gaudi, Ohio State University, Chair, Astrophysics Subcommittee
James Green, University of Colorado
Robert Kirshner, Harvard University
Robert Lindberg, Jr., University of Virginia, Chair, Planetary Protection Subcommittee
Janet Luhmann, UC Berkeley, Chair, Planetary Science Subcommittee
Carle Pieters, Brown University
Mark Robinson, Arizona State University
Steven Running, University of Montana, Chair, Earth Science Subcommittee
Elaine Denning, NASA Headquarters, *Executive Secretary*

NASA Attendees

Barbara Adde, NASA Headquarters
Steve Clarke, NASA Headquarters
Catharine Conley, NASA Headquarters
David Content, NASA GSFC
Rebecca Doroshenk, NASA
Michael Freilich, NASA Headquarters
Neil Gehrels, NASA GSFC
Kevin Grady, NASA GSFC
James Green, NASA Headquarters
John Grunsfeld, NASA Headquarters
Hashima Hasan, NASA Headquarters
Jeffrey Hayes, NASA Headquarters
Kathy Hillen, NASA
Paul Hertz, NASA Headquarters
Mona Kessel, NASA Headquarters
Peg Luce, NASA Headquarters
Patrick Lyman, NASA
Hank Margolis, NASA
Jeff Morrill, NASA Headquarters
Jeffrey Newmark, NASA Headquarters
Arik Posner, NASA Headquarters
Christy Rivera, NASA Headquarters
Kartik Sheth, NASA Headquarters
Eric Smith, NASA Headquarters
Erin Smith, NASA Headquarters
Jeremy Stembler, NASA
Elsayed Talaat, NASA Headquarters
Lucia Tsaoussi, NASA Headquarters
Craig Tupper, NASA Headquarters
Greg Vane, NASA JPL
Pete Vrotsos, NASA Headquarters
Mary Voytek, NASA Headquarters

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Badri Younes, NASA Headquarters
Cheryl Yuhas, NASA Headquarters

Non-NASA Attendees

Marc Allen, Odonata Research
John Evans, GST Inc.
Charles Holmes, self, Chair, Ad Hoc Big Data Task Force
Grace Hu, OMB
Walter Secada, University of Miami
Elizabeth Sheley, Ingenicomm
Ana Wilson, Ingenicomm

Teleconference/Webex Attendees

Damara Arrowood, NASA
Stephen Clark, Space Flight Now
Grace Hu, OMB
Nadia Iglesias, NASA JSC
Tamara Jernigan, Lawrence Livermore Lab
Amy Kaminski, NASA Headquarters
Jennifer Kearns, NASA Headquarters
Robert Leamon, NASA MSC
Kristin Lewis, NASA Headquarters
Michael Liemohn, University of Michigan
James Lochner, USRA
Betsy Pugel, NASA Headquarters
John Rummel, SETI
Ellen Stofan, NASA Headquarters
Anne Verbiscer, University of Virginia
Darrel Williams, GST
Chris Womack

Appendix B
NAC Science Committee Membership

Dr. Bradley M. Peterson (Chair)
Ohio State University

Dr. Susan Avery
Woods Hole Oceanographic Institution

Dr. Jill Dahlburg
Naval Research Laboratory

Dr. Douglas Duncan
University of Colorado

Dr. B. Scott Gaudi
The Ohio State University

Dr. James C. Green
University of Colorado

Dr. Robert Kirshner
Harvard University

Dr. Robert Lindberg
University of Virginia

Dr. Janet Luhmann
University of California, Berkeley

Dr. Carle Pieters
Brown University

Dr. Mark S. Robinson
Arizona State University

Dr. Steve Running
University of Montana

Dr. Harlan Spence
University of New Hampshire

Dr. David Spergel (ex officio)
Princeton University

Ms. Elaine Denning (Executive Secretary)
NASA Headquarters

Appendix C
Presentations

1. SMD FY 2017 Budget Presentation to the NAC; *Craig Tupper*
2. Astrophysics Division Update/Astrophysics Subcommittee Report; *Paul Hertz, Scott Gaudi*
3. WFIRST; *Neil Gehrels, Kevin Grady*
4. Science @ NASA; *John M. Grunsfeld*
5. "The Role of the Terrestrial Biosphere in Global Climate and Carbon Cycles;" *Steve Running*
6. Earth Science Division Update/Earth Science Subcommittee Report; *Michael Freilich, Steve Running*
7. Heliophysics Division Update/Heliophysics Subcommittee Report; *Steve Clarke, Jill Dahlburg*
8. Big Data Task Force; *Charles Holmes*
9. Planetary Protection Subcommittee Report; *Robert Lindberg*
10. Planetary Science Division Update/Planetary Science Subcommittee Report; *James Green, Janet Luhmann*
11. Nexus for Exoplanet System Science (NExSS); *Mary Voytek*
12. Space Communications and Navigation; *Badri Younes*

Appendix D

**NASA Advisory Council
Science Committee
Meeting
March 10-11, 2016**

**NASA Headquarters
Room 3H42**

Agenda

Thursday, March 10

9:00 – 9:15	Opening Remarks / Introduction of Members	Ms. Elaine Denning Dr. Bradley Peterson
9:15 – 9:45	NASA Science Mission Directorate FY17 Budget	Mr. Craig Tupper
9:45 – 10:45	Astrophysics Division FY17 Budget and Update WFIRST Astrophysics Subcommittee Report	Dr. Paul Hertz Dr. Neil Gehrels Mr. Kevin Grady Dr. Scott Gaudi
10:45 – 11:30	Discussion with SMD Associate Administrator	Dr. John M. Grunsfeld
11:30 – 12:30	LUNCH – Member Research Presentation "The Role of the Terrestrial Biosphere in Global Climate and Carbon Cycles"	Dr. Steve Running
12:30 – 1:30	Earth Science Division FY17 Budget and Update Earth Science Subcommittee Report	Dr. Michael Freilich Dr. Steve Running
1:30 – 2:30	Heliophysics Division FY17 Budget and Update Heliophysics Subcommittee Report	Mr. Steve Clarke Dr. Jill Dahlburg
2:30 – 2:45	BREAK	
2:45 – 3:30	Big Data Task Force	Dr. Charles Holmes
3:30 – 3:35	Public Comment	
3:35 – 5:15	Discussion	
5:15	ADJOURN	

Friday, March 11

8:15	Re-Open Meeting	Ms. Elaine Denning Dr. Bradley Peterson
8:15 – 8:30	Planetary Protection Subcommittee Report	Dr. Robert Lindberg
8:30 – 9:30	Planetary Science Division FY17 Budget and Update Planetary Science Subcommittee Report	Dr. James Green Dr. Janet Luhmann
9:30 – 10:00	Nexus for Exoplanet System Science (NExSS)	Dr. Mary Voytek
10:00 – 10:45	Space Communications and Navigation	Mr. Badri Younes
10:45 – 10:55	<i>BREAK</i>	
10:55 – 12:15	Discussion and Wrap-Up	
12:15	<i>ADJOURN</i>	