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MEETING (TELECONFERENCE) REPORT

Bradley Peterson, Chair

Elaine Denning, Executive Secretary

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Opening Remarks

Ms. Elaine Denning, Executive Secretary of the Science Committee (SC), called the meeting to order, made administrative announcements, and introduced Dr. Bradley Peterson, Chair of the SC. Committee members introduced themselves. Dr. Jeffrey Newmark, newly appointed Deputy Associate Administrator for Research for the Science Mission Directorate (SMD), was congratulated on his new position.

Heliophysics Division (HPD) Update

Ms. Margaret Luce, Division Deputy Director, gave a briefing on activities in the Heliophysics Division (HPD). HPD continues to meets its obligations to enhance preparedness as laid out by the White House's 2015 National Space Weather Strategy. Recent science highlights in heliophysics include important data resulting from a magnetic reconnection event observed at the electron scale by the Magnetospheric Multiscale (MMS) mission. A special issue of the journal Geophysical Research Letters will be devoted to this event; it is an exciting time with much new information coming out. The Interstellar Boundary Explorer (IBEX) continues to take measurements of the boundaries of interstellar space; its data on interstellar oxygen and helium are giving a more accurate picture of the interstellar medium. The MinXSS (Miniature X-Ray Solar Spectrometer) cubesat, recently deployed from the International Space Station (ISS), is helping to fill an important data gap by studying Sun's soft x-rays. HPD also hosted a student outreach event, RockSat-X, at the Wallops Island facility, giving hands-on experience to future heliophysics scientists.

The HPD budget distribution is devoted largely to development (54%). Operating missions constitute 12% of the budget, and funds are steadily increasing for Research and Analysis (R&A), at 11% currently. Fiscal Year (FY) 2017 contains an increase related to mandatory investments in cubesats, a further R&A increase, and the space weather initiative. HPD is looking forward to an exciting two years, which will see five launches, the first of which is the Space Environment Testbed (SET) in September 2017, followed by the Ionospheric Connection Explorer (ICON) and Global Observations of the Limb and Disk (GOLD) in October 2017 and April 2018, respectively. Two missions to the Sun will be launched in 2018: Solar Probe Plus, and the Solar Orbiter Collaboration (SOC) in partnership with the European Space Agency (ESA). NASA is providing the launch vehicle and two instruments for SOC. The cadence of heliophysics missions will be increasing as per recommendations from the Decadal Survey with regard to the Explorer missions. HPD has just received proposals from its 2016 Small Explorers (SMEX) Announcement of Opportunity (AO), and is preparing for the next Decadal mission, Solar Terrestrial Probe (STP)-5. Reformulation work has begun on the Geospace Dynamics Constellation. HPD's operating missions are all characterized as Green (the mission is proceeding to meet science requirements) at present. The Solar Terrestrial Relations Observatory (STEREO) mission celebrated its 10th anniversary this October, which was marked by a presentation at the National Air and Space Museum.

Most HPD missions are in an extended phase. The Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI) mission has experienced some battery deterioration, and other minor issues that are being handled successfully. Attempts to contact STEREO B have finally borne fruit. It was contacted on

August 20 after 22 months of silence. While control of the spacecraft has not yet been re-acquired, attempts will continue on a monthly basis, through 2017, to mitigate further spacecraft deterioration. At present, STEREO B is not favorably aligned to allow its solar panels to charge up.

ICON completed its Key Decision Point (KDP)-D milestone on August 26. Ms. Luce was optimistic that a Master Avionics Unit failure would be rectified by November. ICON remains scheduled to launch on a Pegasus rocket in October 2017. GOLD is slated to launch on a commercial vehicle delivering a communications satellite. GOLD will hold its pre-ship review in November 2017, and launch in April 2018. The Solar Probe Plus observatory integration phase is going very rapidly and smoothly, despite concerns about its thermal protection system (TPS), which have since been allayed. There is a potential delay in the Solar Wind Electrons Alphas and Protons (SWEAP) instrument delivery schedule due to a workforce issue at the Smithsonian Astrophysics Observatory. The perihelion orientation for Solar Probe Plus will be 9.6 solar radii, which is inside the acceleration region of solar wind. For the Solar Orbiter Collaboration, NASA is contributing a heavy ion sensor (HIS) and Solar Orbiter heliospheric imager (SoloHI), which are currently being prepared for shipment to the European Space Agency (ESA). The ESA mission schedule is tight; NASA is hoping for an October 2018 launch, and is retaining reserve in case the launch is delayed.

In R&A, the HPD 2015 ROSES (Research Opportunities in Earth and Space Science) competition is complete. HPD ROSES 2016 has just completed its Guest Investigator (GI) program, and is releasing a special GI announcement for MMS; Step-1 proposals for the latter are due in November. Step-1 proposals received for Grand Challenge Research and for Living With a Star (LWS) focused science topics numbered at 44 and 71, respectively. The U.S. Participating Investigator (USPI) program, part of the SMEX AO, received 5 proposals; these enable principal investigators (PIs) to participate in foreign missions. NASA is preparing for the total solar eclipse event across North America in Summer 2017, and to that end HPD has released a special research announcement to fund science that can be done only at that time. Approximately $800K has been put aside for that activity; HPD is working with other divisions in SMD to also fund this work. The Sounding Rockets program has enjoyed a steady complement of launches from the Wallops and White Sands facility, and is maintaining a typical pace. HPD continues to pursue international partnerships, and recently signed an agreement with the Korean Astronomy and Space Science Institute, to explore areas of common interest. A working group has also been established. HPD is also working with the Indian Space Research Organisation (ISRO), and has established a 12-member multilateral science objectives team (SOT) with ESA and JAXA, to relook at a Solar C concept. Its draft report is due in April 2017.

Regarding the evolution of Federal Advisory Committee Act (FACA) changes to the NAC, Ms. Luce said she had requested that HPS give specific feedback on focused science topics in the LWS program, and was looking forward to new possibilities. She closed by updating organizational changes: a Chief Scientist position will soon be filled, as the division has nearly completed interviews for this new position in HPD. Some senior staff have been promoted, leaving a few other vacancies.

Heliophysics Subcommittee (HPS) Report

Dr. Jill Dahlburg, Chair of the Heliophysics Subcommittee (HPS), opened her presentation with an image from the extreme ultraviolet (EUV) imaging spectrometer on NASA/JAXA's Hinode satellite, an image of a coronal loop with accompanying temperature gradients. These temperature data points are critical to modeling a coronal loop of such size. Dr. Dahlburg noted that HPS has gained some new members, and touched on a few key topics at the HPS's August meeting. It was noted that Dr. Newmark is now the Deputy Associate Administrator for Research of the SMD, and Dr. John Lee has moved to the position of Division Director of the Joint Agency Satellite Division (JASD).

At the August meeting, HPS addressed three main topics, one of which is High End Computing (HEC). Dr. Tsengdar Lee briefed the subcommittee on the severe oversubscription of NASA's HEC facilities, which is a new problem. Physically, the facility is full. Dr. Lee described his vision for plug-in modules to be installed at Ames Research Center, which will accommodate new HEC hardware. HPS has recommended a survey across all the agencies that do discovery research (e.g., NSF, DOE, NNSA (National Nuclear Security Administration), DOD), to determine the total need for HEC. Dr. Peterson asked if the module arrangement at Ames would provide sufficient capacity to NASA, and asked how long it would take to build, noting he had been receiving informal complaints about the inability to do modeling. Dr. Dahlburg deferred the question to Dr. Lee, who was to brief the SC on this subject on the following day. The second topic of note by HPS was cubesat classification, specifically that research-level cubesats and formal mission cubesats have very different risk tolerances levels. Dr. Dahlburg and HPS felt the entire science community should hear about these risk distinctions in order to be able to use cubesats more effectively. HPS considered a third topic, related to recent FACA changes, as each of the four SC subcommittees associated with the SMD divisions will now become FACA committees. HPS will now have reports aimed directly to itself rather than to NASA Headquarters. One of these reports was from the LWS Target Research and Technology (TR&T) Steering Committee, which presented 15 draft science topics to HPS on October 25 via telecom. HPS reviewed, assessed, and accepted the report, and forwarded it to the HPD. At the end of the process, she noted that there was broad support for all the topics identified in the report. Division Director Steve Clarke stated in response to the report that he wanted to be as inclusive as possible for the whole community.

Dr. Dahlburg addressed the HPS grading of the Government Performance and Results Assessment Modernization Act (GPRAMA) exercise that analyzed HPD's three strategic objectives, which took place during the August meeting. After two days of deliberation, HPS concluded that all three HPD performance goals had been met, reflected in particular by major recent progress in fundamental space environmental exploration, the achievement of significant new insights into how solar imaging can be used to predict coronal mass ejections (CMEs), and the increasing benefits gleaned from multi-year and multi-satellite data sets. An example of the latter is the important data set that has accrued from increased sampling of the Earth's inner magnetosphere through the Van Allen probes; these data are now being used to improve modeling and analysis algorithms. Dr. Peterson noted the occurrence of a recent geoeffective storm that disrupted communications and grounded air traffic, which illustrated the importance of the Space Weather Strategy in addressing potential Carrington events, as well as frequent small "brownouts" in the electrical grid.

NAS Extended Missions Study

Drs. Harvey Tananbaum and Vicky Hamilton presented results of a National Academies of Science (NAS) study of the NASA science mission extension and Senior Review (SR) process. Dr. Tananbaum reviewed the statement of task, which was to examine the science benefits of mission extensions; the SR process; the cadence of SRs; the balance between new and extended operating missions for science return; and innovative cost reduction approaches. The committee started its work one year ago, and its report was delivered to NASA in late August 2016. The study was commissioned by SMD. Overall, the committee felt that NASA does an excellent job with SRs and praised the value of its extended missions. No major criticisms resulted from study efforts.

The study committee held two meetings which largely involved NASA's former SMD Associate Administrator Dr. John Grunsfeld, and the SMD Division Directors, the National Oceanic and Atmospheric Administration (NOAA), ESA, Congressional staffers past and present, mission teams, and past SR chairs. The third meeting focused on findings and recommendations. The primary study finding is that extended mission science at NASA is productive and valuable. Examples include the Voyager mission, an extended mission (EM) poster child now at the edge of the heliosphere with more than 30 years of science discovery following the prime mission phase. The Hubble and Spitzer space telescopes continue to make new discoveries, such as the presence of distant galaxies that harbor stars forming at a rate more rapidly than previously known in the early universe. Aqua and Terra have provided important findings on the Greenland ice sheet; the STEREO mission achieved a full, 360-degree image of the Sun for the first time; the Mars Exploration Rovers (MERs) identified habitable hydrothermal environments on Mars; and the Lunar Reconnaissance Orbiter (LRO) provided evidence of water ice in the shadow regions of the Moon. Extended mission science is truly a bargain. There are 45 extended missions in progress at NASA, and 15 operating missions in prime phase. Approximately 75% of missions are EMs, and they account for only 12% of the SMD budget. The study concluded that many EMs have made important discoveries through various means: new targets, clever use of data, new destinations, long-baseline data sets, and the tallying up of infrequent events that can provide power to some statistics. Finally, extended phase missions are a vital contribution to NASA's science goals.

Specific recommendations

The NAS Extended Missions Study recommends that NASA SMD policy documents formally articulate the intent to maximize science return by operating spacecraft beyond their prime mission provided the spacecraft are capable of producing valuable science data and funding can be identified, making extensions the rule rather than the "exception." In addition, the study recommends that NASA strongly support a robust portfolio of extended-phase science missions, including advanced planning and sufficient funding to optimize science return. NASA should allow mission teams to re-propose with an innovative, possibly less scientifically ambitious, approach at reduced cost and increased risk, should their mission be recommended for termination at SR due to funding limitations rather than limited science return.

The study recommends a three-year Senior Review cadence, instead of two. This change would require a change in authorization language by Congress. NAS has briefed the House Science Committee staff on this recommendation, which seemed to be received positively. Dr. Tananbaum also noted that the Earth Science Division (ESD) does annual technical reviews, and the study further recommends that the other

SMD divisions do similar technical reviews keeping them moderate in scope and focused on changes since the preceding review, which would lessen the risks associated with a three-year SR cadence. The principal rationale behind the recommendation to reduce review cadence is the lessening of the burden on proposers and review panels resulting in increased productivity. NASA spends considerable time, effort and money conducting SRs every two years. NAS felt NASA has gotten to a point where spacecraft reliability is reasonably predictable, especially with annual technical reviews. NASA can attain more science objectives and more science value with a three-year review cadence. Dr. Peterson asked if there were any arguments against decreasing cadence. Dr. Tananbaum noted that one SMD division felt the two-year cadence was adequate, but overall there were no substantial arguments against a three-year cadence. Dr. Peterson viewed the recommendation favorably.

The study also issued a recommendation on cadence flexibility: i.e. NASA science divisions should be allowed to conduct reviews out of phase to allow for special circumstances to take advantage of the unique attributes of each division's approach to science.

Range of objectives for Senior Review proposals

To obtain best value, NASA should encourage EM proposals to propose any combination of new, ground-breaking, and/or continuity science objectives. NASA should continue to encourage EMs that target new approaches for science and or national needs, as well as EMs that expand their original science objectives.

Recommendation on SR panels

- Each division should ensure sufficient time for each stage of the SR process, including a minimum of 6-8 weeks from distribution of proposals to panels until the panel meets with the mission teams. Panels should have at least 4 weeks to review proposals, and mission teams should be allowed at least 2 weeks to generate their responses to the panels.
- SMD should assemble SR panels that are comprised primarily of senior scientists, but have some early career members as well, to groom them for participation in future SR panels as well as to introduce new and important perspectives. Panels should be assembled early, and include some continuity of membership from previous SRs to preserve corporate memory.
- NASA division directors should continue to communicate and incorporate best practices. NASA should also state its intention to solicit feedback from its proposal teams and review panels about suitability of proposal content and review process. NASA should respond and iterate as needed, to improve the SR process where possible.

Recommendations on funding for EMs

- NASA should assume that missions are likely to be extended and identify funding in longer-term budget projections.
- NASA should continue to provide resources to promote a balanced portfolio, including a vibrant program of EMs.
- NASA should continue to recognize the importance of science return and should ensure, after the first two Senior Reviews, that both operations and science for high performing missions are funded at roughly constant levels, including inflation adjustments. Further cost cuts after two SRs often disproportionately affect science return.

- NASA should provide open communication and dissemination of information on experience with EMs, applying effective practices during development of ground systems and flight procedures, as well as when planning staffing and budget plans for prime missions and EMs.
- NASA should continue to assess and accept increased risk for EMs on a case-by-case basis. Headquarters, center management, and the mission project should discuss risk posture during technical reviews; all parties should be fully aware of costs, risks, etc.

Dr. Peterson ascertained that EM funding had already been provided for the James Webb Space Telescope (JWST) in the Astrophysics Division budget. Dr. Steve Running, chair of the Earth Science Subcommittee, commented that ESD is a little different from other divisions, and wanted to reinforce the observation that ESD ends up with an increasing load of activity, and with it costs, for maintaining data streams into other government agencies. Dr. Tananbaum affirmed that he had received similar input from Dr. Mike Freilich of ESD, and from NOAA staff. Dr. Peterson resonated with the idea of bringing junior members onto panels, who don't necessarily vote, but would take notes at such reviews. Dr. Susan Avery echoed Dr. Running's comments, with respect to the future responsibilities of HPD and its obligations to national space weather mandates.

Discussion with SMD AA

Dr. Thomas Zurbuchen, the newly appointed SMD Associate Administrator, introduced himself and provided details of his background. Of Swiss origin, Dr. Zurbuchen obtained his Masters and doctoral degrees in physics and mathematics at the University of Bern, where he specialized in building space instruments. He was hired at the University of Michigan, through his relationship with Dr. Len Fisk. He built careers in heliophysics and planetary science, both in teaching and in designing and building instruments. He found the cycle of innovation and engineering to be very exciting. Dr. Zurbuchen worked on several NASA missions, having built instruments for Ulysses, ACE (Advanced Composition Explorer), Wind, the MESSENGER (MErcury Surface, Space ENvironment, GEochemistry, and Ranging) mission, and Solar Orbiter. Throughout his teaching career, he built engineering programs and some early-stage innovation programs at the University of Michigan.

Dr. Zurbuchen expressed excitement about working with the NASA team. He noted that the best ideas he had worked on were almost never his, but he typically had the ability to make them better. He felt the best ideas arose from diverse teams, not from people that are all the same; and that there must be diversity in all dimensions, not just one or two. He was currently focused on getting to know the SMD team and hearing about the thinking that drives their science questions. The work being done presently and within the next three years is the priority, as is preparing for the transition. He wanted to help NASA continue its successes (e.g., JWST) and to be a positive factor in what he believed was the best to come for NASA. His approach to the trades of innovation and risk rested critically on evolving a tool set that would be appropriate to answering new science questions. Somewhere in the middle of the science and technology loop is the magic space of Class D missions, which are more PI-centric. He reported having attended a milestone review for Cyclone Global Navigation Satellite System (CYGNSS) (which will measure the surface winds of hurricanes), and was impressed by the ability to obtain more frequent radar measurements at a much lower cost than could be gathered, for example, by a fleet of hurricane hunter aircraft. He felt that not every solution has this low-cost combination of innovations, and that there is no

such thing as a $100M JWST, but there are other comparable solutions out there. Science scaling converges with improvements in systems engineering.

Dr. Mark Robinson offered his congratulations and asked for Dr. Zurbuchen's thoughts on more collaboration between Human Exploration and Operations Mission Directorate (HEOMD) and SMD as the plan evolves for human space flight. Dr. Zurbuchen said he had spent a lot of time with both HEOMD and SMD, and found the alignment to be better than he expected. He felt there was tremendous clarity on understanding the joint properties of human exploration and science in missions already, as NASA works to improve technologies in cis-lunar space in the journey towards Mars. He acknowledged that the picture could be very different after the Presidential election. For now, he was learning more about budgetary principles and constraints, as these will define the solution space. Dr. Peterson asked what was most surprising about the job. Dr. Zurbuchen said the number of meetings was quite substantial; while he had spent many years on the Space Studies Board (SSB) and thought he knew NASA pretty well, he found out that there is much more than meets the eye. There are so many "gems" he never knew about, such as planetary defense. He said he enjoyed seeing the various "dashboards" and metrics that guide the thinking.

Dr. Dahlburg mentioned the three new driving commercial powers in space, (SpaceX, Virgin Galactic, etc.) and asked how he saw SMD collaborating with them. Dr. Zurbuchen felt that the commercial industry has broad value to the U.S., much in the same way that the Global Positioning System (GPS) proved an unexpected benefit from the Naval Research Laboratory (NRL), for example. The small satellite industry is growing rapidly. Each one of the commercial space business models is a bit different, and not everyone will survive. He thought that NASA partners well with industry when they are there and that NASA should look at hosted payloads with these new commercial interests. One thing that can be hard is the timescale of (industry) change versus the time NASA has to adapt. He did think NASA does better with industries with a slower ramping speed. Dr. Peterson asked how SMD might engage the new technology companies. Dr. Zurbuchen said that NASA is implementing the Decadal Surveys, and is creating growth and stability as guided by a consensus document. The Agency can take advantage of new mission types that could be done with cubesats, or by the use of data buys. The framework, however, is the guidance by the National Academies. NASA should partner to get the science, and learn how to do this as it goes forward.

Dr. Robert Lindberg commented that he is participating in a planetary protection conference, and echoed Dr. Zuburchen's comments on collaborations. Dr. Zuburchen noted that planetary protection is an interesting opportunity and challenge; there are more players now, and COSPAR (Committee on Space Research), ESA (European Space Agency) and NASA are largely aligned, but not always on the same page. The discussion is just as important with HEOMD as it is with the internationals.

STEM Activation Update

Ms. Kristen Erickson gave a briefing on the evolution of SMD's education restructuring efforts. She expressed excitement at having Drs. Zurbuchen and Newmark on board at SMD. SMD's Science Engagement and Partnerships function is now fully staffed. Twenty-seven cooperative agreements were announced in 2016, with a budget of $37M. The job is still a very daunting outcome, trying to reach the

"K to gray" populations, learners of all ages. SMD is doing this more efficiently through leveraging existing partnerships, and is still in the baselining phase of the effort.

"Science STEM Activation" is the new name of the SMD Education effort, and reflects the more active phase of a potential 10-year relationship with the 27 awardees (posted at nasa.gov/press-release). The objectives of Science STEM Activation are to enable STEM education, improve U.S. scientific literacy, advance national educational goals, and maintain a strong relationship with NAS. Also, with support from Administrator Bolden, there is now a new seat on the SC for STEM education; this means that we have two of the foremost thought leaders in this country, Drs. Secada and Duncan, on the committee.

In January 2016, Year 1 funding was awarded, and a kickoff meeting was held. All 27 awardees have submitted Evaluation Plans to include descriptions/plans for audience needs assessments; logic models; and reporting and top-level metrics. Earth and space sciences are how the concepts are first taught in U.S. schools, thus this will be the way the concepts will be presented by the awardees. Each awardee must document evidence-based needs associated with each project. A "Meeting of Experts" to evaluate awarded projects is now under contract. A listserve has been established (Science WOW!; it comes out "Weekly on Wednesdays"), and its latest accomplishment is the establishment of a Space Science Badge for the Girl Scouts of America. The next milestone is the Baseline Review meeting, which is scheduled for the week of November 14. The review will ask how achievements will be disseminated, and how the awardees collaborate with each other. Science STEM Activation did not fund as much formal education as originally anticipated. There is currently a task with the NAS that includes a meeting next week with NASA subject matter experts in all four disciplines, as well as PIs associated with the 27 awardees, and with Dr. Secada. With the eventual output from this NAS task, Science STEM Activation will go out with a targeted call in the 2018 timeframe. Two hundred-fifty STEM toolkits, such as a training toolkit for the 2017 solar eclipse, are being assembled. There are 44 Challenger centers in the collective, many of which are in rural areas, which will also be collaborating with the STEM toolkit effort. NASA will have broadcast sites identified by the end of the year in preparation for the eclipse. The entire North American continent will see at least a 60% eclipse, and NASA is making sure safety plans are established. A Great American Eclipse group, and plans for DSCOVR imagery are under way. ISS astronauts may show some coverage. Student balloon experiments at Montana State and airborne experiments at Armstrong Research Center are in the works. The LRO camera will also witness the event. The websites for the event are: https://eclipse2017.nasa.gov, in addition to https://nasa.gov/eclipse. Updates will be posted to http://science.nasa.gov/learners.

Science STEM Activation is working with the Office of Education on a Blanket Purchase Agreement for external evaluation purposes, and also with the NAS Board on Science Education. At present, areas of concern include budget uncertainty; NASA will need $42M per year to completely restructure Science STEM Activation. There is a risk of stakeholders disconnecting from Science STEM Activation and combining with Education.

Dr. Dahlburg remarked on the impact of scientist STEM visits; that learning can occur when a memorable activity is done such as arranging the kids in formations of the Sun, Moon and Earth. Ms. Erickson agreed that this is the way to make it real. She stressed that it is incumbent upon everyone in the science and

education communities to share the last step of the scientific method, which is to share the result. Even more responsibility lies with NASA's tax-supported STEM education efforts. She recommended blogging, Twitter, etc. to increase scientific literacy and to encourage a new generation of active learners. AAAS (American Association for the Advancement of Science) is very much engaged in getting people to question outcomes—Citizen Science is one way to do this. Dr. Avery asked how NASA was connecting the new STEM approach with issues of everyday importance, such as bridging science with climate change issues. Ms. Erickson said she has had staff ask specific questions to determine these needs in whatever learning environment is identified. STEM is also collaborating with the NASA GLOBE (Global Learning and Observation to Benefit the Environment) program, getting data to inform future efforts. Dr. Lindberg asked about reaching lifelong learners. Ms. Erickson mentioned a classroom lesson using raw images of the Sun taken from Hinode, wherein teachers ask kindergarten students to draw what they see. Kindergarten students drew their interpretations of the raw image, and remarkably identified their own concepts about sunspots and CMEs. These same raw images can be taken up the ladder of education, all the way to citizen science groups. Dr. Walter Secada felt that efforts such as these are the best way to maximize a small investment and figure out how to do it right.

Earth Science Division (ESD) Update

Dr. Michael Freilich presented an update on the Earth Science Division (ESD). ESD has the key objective of understanding the Earth as an integrated system, and to take the research to develop focused products that benefit all of society. ESD represents challenging, interesting, and important work. Its four major activities are: taking measurements from unique points in space; frequent, high-resolution measurements; global coverage; and uncovering the connections between scales and quantities. About 61% of the ESD budget is devoted to measurements. The research component is the integrating function, representing about 34% of the budget. Societal benefit and capacity-building (applications program), and technology development constitutes the remainder of the budget. For FY17 the ESD budget is $1966M. The budget jumps significantly in FY17, then becomes consistent with the FY16 Presidential Budget Request (PBR) for the out-years. ESD has enjoyed relative programmatic stability from the Administration. Dr. Dahlburg asked about HEC capacity. Dr. Freilich said ESD had passed it a long time ago; and because ESD has responsibility for both governance and execution for HEC, there have been some recent executive decisions to increase HEC capacity for the agency.

ESD's major program elements in R&A are: discipline-based programs such as carbon cycle and ecosystems; climate variability and change; atmospheric composition; global water and energy cycle; Earth surface and interior; and global weather. Interdisciplinary and cross-disciplinary programs are supported by field campaigns and enabling capabilities such as airborne science, scientific computing, calibration/validation and complementary surface observations, and modeling and assimilation for community usage. Applied Sciences involves leveraging satellite measurements and new scientific knowledge. The applications program addresses natural disasters and ecological forecasting, capacity building, and satellite mission/information use planning. The Earth Science Technology Office (ESTO) is a sustained investment for enabling Earth research, applications and flight missions.

There are currently 19 operating missions in ESD— imminent launches include Cyclone Global Navigation Satellite System (CYGNSS) in December, and the Stratospheric Aerosol and Gas Experiment

(SAGE-III) to ISS in January. There will be considerable activity in cubesat launches through 2018. Venture (EV) class selections continue: solicitations include suborbital (EVS), instruments (EVI) (competed every 18 months), and missions (EVM). The key for any Venture class project is that it must be kept in the cost box or it will be cancelled. This rigor ensures a stable schedule and cadence. EVS and EVM are solicited every four years on an alternating schedule. The Venture class is walled off in the budget, and remains on schedule and fully funded.

Earth Venture missions include small satellite constellations such as CYGNSS, which is comprised of 8 satellites launched on one vehicle. It will measure surface/sea interactions in developing cyclones. Another is the Time Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats (TROPICS) mission. There will be a $30M augmentation to ESD in FY18 for the acquisition of measurements by small-satellite constellations. ESD put out a request for information (RFI) about the feasibility of purchasing from the private sector, and evaluating small satellite data products that might augment or replace NASA-collected data, and has received strongly positive industry response. There likely will be a request for proposals (RFP) if Congress appropriates the FY17 PBR for ESD.

ESD also investing in low-cost (<$15M) launches into low-Earth orbit (LEO), termed Venture Class Launch Services (VCLS), a joint ESD/NASA Launch Services Program (LSP) initiative that is funded with $10M from ESD. NASA continues working with the U.S. Geological Survey (USGS) to move forward on Sustainable Land Imaging (SLI), building on the Landsat legacy. Landsat 9, essentially an upgraded Landsat 8, is moving forward well. There are six near- and long-term instruments in development under SLI Technology, including a compact hyperspectral prism spectrometer.

ESD is just starting the Plankton Aerosol Cloud and Ocean Ecosystem (PACE) mission, targeted for launch no later than 2022. PACE is being developed with a design-to-cost approach. Directed to Goddard Space Flight Center (GSFC), NASA is challenging the center to maximize the capability for the cost. There are no specific initial requirements; PACE will be designed through iteration, letting the engineers hone and determine the requirements based on cost.

Interagency Satellite Needs Process

NASA has accepted the role of considering the satellite needs of the other Federal agencies, which will be determined through the Satellite Needs Working Group (SNWG), which determines common measurement requests, aggregation and categorization. NASA will document for the Office of Management and Budget (OMB) and Office of Science and Technology Policy (OSTP) how it adjudicates each request. NASA is not required to actually satisfy the identified needs.

Missions in development

ICESat-2 is a Tier 1 Decadal Survey mission, which will measure ice surface topography and vegetation canopy at low latitudes. After a rocky development phase, which included a laser failure during environmental testing, corrective plans will be finalized and corrective actions implemented. The mission understands the root cause of the failure. The launch has been delayed by several months to October 2018, with minimal cost impact. For Sentinel-6, a precision altimetry mission in the European Copernicus

program, NASA will be playing a key role, providing an instrument suite and a launch vehicle. The launch readiness date for Sentinel-6 is no earlier than 2020.

Dr. Freilich concluded with science highlights, including NASA observations and mapping information during the historic Louisiana flooding event of 2016. ESD also briefly diverted an airborne campaign to help search for SpaceX debris at Kennedy Space Center (KSC) after a vehicle explosion on September 28.

Dr. Avery congratulated ESD on considering data buys, and asked about the resultant information products: are these raw, processed, or open-source algorithms types of data? Dr. Freilich answered that it was all of the above, and that ESD is interested to see what value the products might have to advance the science. Dr. Avery posed a strategy question for the climate community, citing a knowledge and data gap regarding the stratospheric, mesospheric and tropospheric exchange of water vapor. Dr. Freilich said that lots of people are thinking about this, and the proposing community clearly has some of these missions in mind. Airborne campaigns are looking at troposphere/stratosphere exchange processes. ESD expects to get some advice on the issue in the next Decadal Survey. Dr. Lindberg commented that the data buy concept is an interesting one and asked if ESD had looked back at data from the Sea-Viewing Wide Field-of-View Sensor (SeaWIFS). Dr. Freilich said the ESD focus was on a different kind of data buy; i.e. smallsat commercial constellations.

Earth Science Subcommittee (ESS) Report

Dr. Steve Running, Chair of the Earth Science Subcommittee (ESS) presented a short briefing, noting that ESS has not met in person since the last SC meeting. The ESS held a teleconference on September 15 to vote on GPRAMA topics. All focus areas: Earth radiation balance, air quality, ozone; progress in predicting extreme weather events; and progress in the global carbon cycle, were voted Green in unanimous decisions.

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Ms. Denning re-opened the meeting and turned it over to Dr. Peterson, who remarked briefly on how the Science Committee might change its operations due to recent FACA restructuring, and asked committee members to formulate their opinions on the matter.

Planetary Science Subcommittee (PSS) Report

Dr. Clive Neal gave a briefing on the latest activities of the Planetary Science Subcommittee (PSS), whose latest membership roster has been finalized. PSS had a full agenda at its September meeting, with much discussion about PI-run analytical laboratories and a NAS study on potential loss of capability. PSS issued 8 findings and 1 action item, and wished to present 2 findings to the SC: the first on special regions on Mars. PSS recommends that the Planetary Protection Subcommittee (PPS) and PSS co-organize a workshop to better define naturally occurring special regions on Mars, and also to assess the potential of "induced special regions" caused by heat from radioisotopic thermal generators (RTGs), high-velocity impacts, or other transient temperature increases that could melt ice on the surface of Mars. Such a

workshop could also include Ocean Worlds to accommodate current planning for a mission to Europa, to put some statistics on actual risk. The plausibility of the process must be well understood in order to develop protocols for the prevention of both forward and backward planetary contamination. PSS feels that the Mars Program Office has been dealing with this in an *ad hoc* way that lacks rigor.

Dr. Neal also brought forward a PSS finding on the Deep Space Network (DSN), expressing alarm at the DSN budget, which could remove an existing redundancy for future deep space missions. The shrinking budget will have major effects on science missions to the outer solar system. The workload is increasing and the budget is decreasing. PSS issued an action item to DSN to provide information on unscheduled down times that have occurred over the last 5 years that may possibly indicate an ongoing degradation process. PSS feels DSN is an accident waiting to happen, and wanted to announce it loud and clear.

Dr. Lindberg commented on the first finding, adding that it was wonderful to have such an engaged conversation with PPS and PSS. PPS has not yet taken up the recommendation as it has not met since June, but he expected the finding to have wide support. PPS plans to hold a joint meeting with PSS; this subject has already been brought to the NAC. Dr. Neal offered to attend the next PPS meeting to discuss its special regions workshop findings.

Planetary Science Division (PSD) Update

Dr. Jonathan Rall, Planetary Research Director, provided an update on the Planetary Science Division (PSD). There are 11 missions in extended operations, including some ESA missions. Three missions are in prime operations, and two are in formulation. The Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer (OSIRIS-REx) mission to the asteroid Bennu launched in September; in the same month, ESA closed out the Rosetta mission by landing on its target comet. Two Discovery missions are in operations—Dawn and LRO. NASA delivered the Strofio instrument to ESA for the Bepi-Colombo mission. PSD is on track to launch the Mars Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSIGHT) mission in 2018. Discovery 2014 missions will be down-selected by the end of this year. In New Frontiers, the Juno mission to Jupiter has run into an anomaly that has delayed a main engine burn designed to put the spacecraft into its 14-day science orbit. Juno has since come out of safe mode, and the mission hopes to soon begin its baseline polar orbits. At around orbit 20, at the 53-day mark, Juno will experience an eclipse from which it might not recover. The first data from Juno has indicated large cyclonic storms and aurorae at the south pole (imaged in near to mid-infrared wavelengths).

The next New Frontiers AO contains a comet sample return mission, a lunar Aitken Basin sample return, a Venus *in situ* explorer, a Saturn Probe, a Titan mission theme, an Enceladus mission theme, and a Trojan Tour and Rendezvous concept. Five of these missions were recommended by the Decadal Survey; PSD added Enceladus and Titan. An AO is targeted for release in January 2017; proposals will be due within 90 days, and down selection will occur in May 2019. PSD is also holding a SIMPLEx cubesat selection for small innovative planetary explorers. One selection is the Lunar Polar Hydrogen Mapper (LunaH-Map) and the other is a cubesat particle aggregation and collision experiment. Three cubesats have been selected for technology development only.

The Planetary Defense Office is currently studying AIDA, a joint NASA/ESA mission that has entered parallel formulation concept studies. AIDA is a combination of the ESA Asteroid Impact Mission (AIM) and NASA DART (Double Asteroid Redirection Test) mission. Under R&A, the PSD R&A ROSES 2016 call is the third call since the re-organization. PSD is about 2/3 the way through on its review of the call. NASA has charged NAS to form an *ad hoc* committee to review the R&A restructuring, which will report out in December of this year. Other NAS planetary studies to date include completed cubesat and Extended Mission studies. NAS will issue a large strategic planetary missions report in August 2017. A new NAS study is planned for NASA's future investment strategy in sample analysis, to determine what analytical capabilities will be needed. The next Planetary Decadal Survey will be tasked before October 2019. Dr. Rall presented science highlights on Charon's dark red poles, and sulfur deposits on the asteroid Ceres.

Dr. Peterson asked about Juno's issues. Dr. Rall said there were two major issues; one was the check valves in the propellant system, which opened very slowly on command. The second issue is the safe mode that occurred just before the second perijove. It is not known whether this latter issue is just a glitch. The mission hopes to do the orbit burn soon. Dr. Neal asked about issues with the lunar mapper concept. Dr. Rall said they had underscoped their propellant system in their first proposal, and should have issued contracts and not grants, with a complete technical and cost estimate. There was also a loss of key personnel, and it became clear that costs were going to grow.

OSIRIS-REx

Dr. Jeffrey Grossman presented a general overview of the OSIRIS-REx mission. Asteroid science exploration is relatively immature at present; there have been 12 asteroid fly-bys since 1991. The NEAR (Near Earth Asteroid Rendezvous) mission in 2000 flew by the S-type asteroid Eros. JAXA's Hayabusa-1 mission returned less than a milligram of microscopic particles from asteroid Itokawa in 2010, confirming that it was an S-type asteroid associated with ordinary chondrites. OSIRIS-REx launched in September, and will explore a primitive carbonaceous asteroid and return a significant mass of sample. This is a $1B mission, including the launch vehicle. The mission PI is from the University of Arizona, it is managed by GSFC, and Lockheed Martin is the contractor. The mission carries an instrument from the Canadian Space Agency (CSA), contributions from the French, and is partnered with the Hayabusa 2 team. OSIRIS-REx's goal is to return a pristine sample to Earth which will provide some clues to the origin of the Solar System; identify organic compounds that may have been introduced to the early Earth; map chemistry and mineralogy; measure the Yarkovsky (solar radiation) effect which changes orbital parameters over time; and provide ground truth for telescopic data. The mission will help make the link between meteorites and their originating asteroids, and document the regolith at the sampling site to the subcentimeter level. The mission will address multiple overarching goals of planetary science: understanding the past, understanding life, and understanding the present and future (i.e. what objects present risk?). The timeline is 2011 through 2023; it will take two years to get to the asteroid. Operations will begin in Summer 2018, and the sample will be returned in September 2023. OSIRIS-REx is likely to provide science for decades, much like the Apollo flights.

The target is the dark and likely carbon-rich asteroid Bennu, a half a kilometer in diameter; it is thought to have a lot of loose regolith. Bennu is potentially hazardous to Earth; the current risk is low, however. Its

trajectory will bring it past Earth in the early 22nd century, which will perturb its orbit. Thereafter, there is a 1-in-2700 chance of Earth impact in the late 22nd century. OSIRIS-REx will have an Earth gravity assist maneuver in a year to get the spacecraft into the plane of Bennu's orbit. Instruments include the OCAMS camera suite; OTES thermal emission spectrometer; OVIRS visible and near-IR spectrometer; OLA laser altimeter; and REXIS (a student contribution), an x-ray imaging spectrometer. A Touch and Go sample maneuver (TAG) uses an articulated arm and nitrogen gas to blow regolith into a sample chamber. Three attempts will be made to obtain a sample. The Level 1 mission requirement is to bring back at least 60 g of sample, but the system can get up to 2 kg into the collector. Samples will be delivered to the curation facility at Johnson Space Center (JSC). The CSA will receive 4% of the sample, and JAXA will get 0.5% of the sample; as much as 75% of the sample will be preserved for posterity. The mission had a perfect launch in terms of target ellipses. Dr. Peterson offered congratulations on a successful start.

Planetary Protection Subcommittee Report

Dr. Robert Lindberg presented a briefing on the Planetary Protection Subcommittee (PPS). There is no progress to report on filling vacancies on the subcommittee; some members had to leave due to perceived conflicts of interest. An effort is underway to secure more international members, which was hindered last year due to the FACA process. Several members of PPS participated in developing a planetary protection (PP) handbook with ESA, and members are staying engaged with the community. Dr. Lindberg reported participating in a COSPAR meeting on planetary protection developments. He expressed growing concern that PPS is not being transitioned into a FACA committee. PPS perceives growing tension between the Planetary Protection Office (PPO) and the Mars Exploration Program, and is concerned that NASA might move to act independently of COSPAR guidelines; this is not in NASA's or the country's best interest. He noted that both he and Dr. Catharine Conley had enjoyed a productive interaction with PSS.

Dr. Peterson thought the Mars 2020 program and PPO had reached an understanding last summer. Dr. Lindberg said he personally perceived that the issues were deferred, but not resolved. Dr. Peterson indicated that the SC will continue to monitor the situation and would make sure the SMD AA remained apprised.

Astrophysics Division (APD) Division Update

Ms. Andrea Razzaghi presented an update on the Astrophysics Division (APD). The APD budget remains healthy at $1.35B, and fully supports JWST, Wide Field Infrared Survey Telescope (WFIRST), and increases in the R&A Program. Two astrophysics missions, Neutron star Interior Composition Explorer (NICER) and Cosmic Ray Energetics And Mass (CREAM), are ready to launch to ISS. APD will hold a Senior Review in 2018. JAXA is considering an X-ray Recovery mission (XRRM) to replace the science that had been expected from its failed Hitomi mission. The NAC recommended that NASA participate in XRRM, and rebuild the x-ray spectrometer it had contributed to the first mission, provided Hitomi problems are resolved. The new mission will be directed rather than competitive.

Recent and upcoming suborbital missions include the Fall FY16 balloon campaigns at Fort Sumner, and the Stratospheric Observatory for Far Infrared Astronomy (SOFIA), which is in the process of completely upgrading its instrument suite. By the end of the decade, SOFIA will carry an entirely new suite of

instruments. APD just received a very positive Mid-term Assessment from the NAS, which contained five recommendations, one of which calls for participation in ESA's Laser Interferometer Space Antenna (LISA) Pathfinder mission; this is being actively pursued.

APD missions in development include The Transiting Exoplanet Survey Satellite (TESS), JWST, Euclid, and WFIRST. NICER, CREAM, and TESS (June 2018) will all launch on SpaceX vehicles, thus APD is looking forward to the SpaceX Return to Flight. JWST remains on track for a 2018 launch. The Optical Telescope Element and Integrated Science Instrument Module (OTIS) is fully assembled and undergoing testing at GSFC. Pathfinder tests are ongoing at JSC. The spacecraft, built by Northrop Grumman, has had all its electronics and harnessing; the solar array is in testing phase. In summary, JWST is making progress; the community engagement period is one year away. WFIRST is also making good progress; starshade compatibility has been incorporated into the Phase A baseline. Overall, the mission is on track to reach TRL (Technology Readiness Level)-6 in new technologies by 2017. An in-guide budget supports a WFIRST launch in the mid-2020s. The Continuing Resolution has had no impact to proceed with plans.

Ms. Razzaghi emphasized that the Decadal Survey remains very important, and is working to ensure that the 2020 committee has the information it needs. APD studies on large mission concepts are well underway; the division is also soliciting concepts for medium-sized missions. Dr. Peterson asked if a coronagraph for WFIRST was still de-scopable. Ms. Razzaghi said that because the coronagraph is a technology demonstration, it won't be held to the same standards as the wide field instrument. It is not de-scopable at the moment. The mission is examining how it fits in with Level 1 requirements.

Astrophysics Subcommittee (APS) Report

Dr. Scott Gaudi presented a briefing on the latest Astrophysics Subcommittee meeting, beginning with science highlights. A composite image of Europa has shown evidence of some emission above the limb of Europa that may represent water plumes. While caution is needed about this interpretation, the image raises hope of in situ sampling of these plumes in a fly by. The Hubble Space Telescope observed TRAPPIST-1 while two of its planets transited the star simultaneously. The data showed no signal of atmospheres of the planets, indicating that either the two planets do not have atmopsheres, or they have Earth-like atmospheres with heavier elements. Kepler/K2 observations of the Pleaides star cluster provided some understanding of how stars spin down over time. More massive stars tended to rotate slowly, while less massive stars tended to rotate rapidly. K2 is looking at another cluster to bear out these conclusions. Chandra observed a supernova remnant, G11.2-0.3, which demonstrated definitively that this supernovae was not associated with the naked-eye astronomical event observed by the Chinese in 386 CE, as was previously thought.

APS membership hasn't changed much. Dr. Mark Devlin had to step down due to time constraints. APS held a teleconference on October 3-4 in which it discussed several topics. Dr. Gaudi noted that it is difficult to deal with contentious topics in a teleconference. APS concurred that the WFIRST budget must be monitored closely as per the mid-decade assessment. APS also heard a briefing on HEC, about which APS encouraged NASA to maintain vigilance. There was also an R&A update, reports from the analysis, groups, a JWST update, an SMD Education update, and an L3 (gravitational wave) Study Team update.

Findings and recommendations

APS approved and endorsed the extension of the NASA-Keck cooperative agreement for another 5 years, and commended NASA for recognizing the synergy between ground-based and space-based astrophysics. APS considered APD's proposal to reduce the number of participants in its named fellowship programs by 30%, and to consolidate the review process into a single selection process, to allocate freed funds to the Astrophysics Research and Analysis (APRA) program. Dr. Gaudi noted that he had recused himself from the discussions on this topic. He reported that a majority of the subcommittee (11/12) voted in favor of consolidating the selection process. He also reported that the subcommittee was split on the issue of reducing the number of named fellows, hence it issued no recommendation. However, the majority of members felt that, if the 30% reduction was to be enacted, the freed funds should not go solely to APRA. Dr. Gaudi also noted that part of the part of the discussion surrounding the reduction of the named fellows involved maintaining balance between the disciplines of the selected named fellows. Dr. Peterson liked the idea of distributing the named fellowships across three different committees, as it would likely reduce the likelihood of blackballing. He was uncomfortable with the idea of one committee. However, Dr. Peterson overall felt this was not an issue the SC should micromanage.

APS also considered a proposed restructuring of the Roman Technology Fellows (RTF) program. APS recommended that APD run the RTF panel in parallel with APRA proposals but set a different standard for selecting proposals as RTF-eligible for early-career PIs. The APS also considered a proposed restructuring of Astrophysics Theory program (ATP) to fund ATP proposals every other year while maintaining the overall budget, with a goal of doubling success rates. On this issue, the APS was strongly divided; 9/16 were in favor of a two-year cycle. Thus, the APS put forth no recommendation. However, the majority of the APS felt that, if the two-year cycle were enacted, that it was critical that the community was informed of this change beforehand.

Dr. Gaudi argued that there were no actionable items to put forward on these topics. Ms. Denning and Dr. Peterson concurred.

Public Comment

Dr. John Rummel expressed his concern about planetary protection's status in the new NAC structure, and pointed out that PPS was set up independently as a way to help avoid conflicts of interest. PPS now seems to have been left to dwindle to a low membership of 6, without international representation, which he felt was not appropriate. Dr. Peterson noted that the NAC structure was still a work in progress.

Big Data Task Force

Dr. Charles Holmes presented the results of the Big Data Task Force's (BDTF) third meeting, which took place at the Ames Research Center and had significant support from the Infrared Processing and Analysis Center (IPAC) at Caltech. He gave kudos to BDTF member Dr. Eric Feigelson for attending the Webex on an 8-hour time difference. The current membership will remain the same, as the last two candidate members have fallen through. Executive Secretary Dr. Erin Smith will be leaving for her new post as GSFC Deputy Observatory Scientist for JWST. Mr. Gerald Smith will take over her role.

BDTF heard briefings from the NASA archives, a follow-up on the Pacific Research Pipeline (PRP) 100Gb/s science pipeline, the Department of Energy's (DOE) Energy Sciences Net (ESNet), and science pipeline "DMZs." Dr. Holmes noted the lack of interest on the East coast or in the middle of country for participating in these new conduits. BDTF plans to bring DOE back to brief on their exascale computing [defined by Wikipedia as computing systems capable of at least one exaFLOPS, or a billion billion calculations per second] efforts, in order to help leverage these assets for NASA purposes. The task force toured the Solar Dynamics Observatory (SDO) Atmospheric Imaging Assembly (AIA) and helioseismic and magnetic imager (HMI) science operations, the Moore Foundation, and the Ames facility itself. Dr. Holmes reported recently attending a New York University summit on advances in the data sciences field and in data-driven discovery. Concluding some old business, BDTF revisited the NSF Big Data Regional Hubs competition. The final procurement cycle is complete and the winners of the "Spokes" awards announced—$11M for 20 awards over a broad range of topics. NSF will be working with these groups over the next few years. BDTF members will re-visit the large NSF Hubs to re-interview PIs, to determine whether NASA should participate in some way. The BDTF work plan is now in research phase, after which results will be gathered at the next meeting, on four focus topics. Members also toured the Pleiades computer at the Ames HECC (High-End Computing Center), and had good discussions.

Dr. Holmes noted that the term "Big Data" was coined at Ames 20 years ago, at a time when the biggest data set was 7.5GB. BDTF heard from the NASA Earth Exchange (NEX), a virtual collaborative that brings scientists together and provides tools and computing power to work on topics of interest. Science at NEX includes imaging of global vegetation biomass, fallow-area mapping in drought conditions, etc.

BDTF also heard a briefing on pipeline processing activities for Kepler data, noting that about 10% of Pleaides computer time is spent on processing Kepler data on exoplanets. The computing time is largely devoted to beating down noise in the data. The same group is preparing for follow-on missions, such as TESS. BDTF will be making a recommendation relative to this processing activity. The Caltech Astrophysics archives were also the subject of a briefing. The Infrared Science Archive (IRSA) enables research that has not yet been envisioned, and similar to other NASA archives, they are expecting growth in the coming years. It is clear that the NASA archives play a critical role in publications. Archives are becoming important as new sources of science research (this is also the subject of a BDTF finding). To accommodate the increasing data volumes, some archives are now proposing that server-side analytics be incorporated, to move some data reduction tasks to the archives. The NASA Exoplanet Archive (NEA) stores metadata, locations, physical attributes, rather than the raw data itself. While the Mikulski Archives for Space Telescopes (MAST) is tasked with archiving raw Kepler data, NEA provides a way for researchers to look at exoplanet parameters. The NASA Extragalactic Database (NED) is collecting metadata as well, which enabled the discovery of a new class of super-luminous galaxies. In the last five years, IPAC has been building on core expertise, diversifying science archives, and determining its future role in NASA's future astrophysics survey missions, such as WFIRST and Euclid. All of the archives are facing large and accelerating growth. BDTF thinks they are on the right path, taking steps, in preparing for the future.

BDTF also heard about cloud computing efforts at Ames, as at GSFC. The NASA Enterprise Managed Cloud Computing (EMCC) Services is looking to see where NASA can take advantage of the commercial

sector's cloud computing services. EMCC is taking the strategic approach of doing the heavy lifting once for the Agency. What can these commercial interests do for NASA science? Mr. Michael Little is working under ESD's Advanced Information Systems Technology (AIST) to do some demonstrations on commercial cloud, reasoning that the best way to learn cloud computing is to use it. BDTF also has a recommendation related to cloud computing.

BDTF plans to meet again in March 2017 at NASA HQ, revisit with program officers, conclude the assessment of SMD's data and processing, and receive a briefing on DOE's exascale project.

BDTF Findings and Recommendations

BDTF issued a finding on "Observing in the Archives" as more and more new research ideas are coming from the archives themselves, the archives can be seen as essentially doubling the scientific productivity of the missions. How is NASA management reflecting on this? Five percent of the budget may be producing half of new original research. BDTF may have some related recommendation on this finding in the future.

BDTF also issued a finding on the AIST efforts in on-ramping cloud computing services for the Agency. BDTF recommends that Kepler/TESS projects should collaborate with AIST to demonstrate the possible utility of moving the exoplanet pipeline processing to a commercial cloud setting, which will free up 10% of Pleiades time.

Dr. Holmes concluded with his customary "Chuck's Soapbox" message, noting that to achieve success in data driven discovery, NASA needs the right skill mix. Domain expertise must be merged with people who have computational skills, and applied math and physics skills.

Dr. Running particularly endorsed the finding "Observing in the Archives," as he saw this as critical to global change science, which requires continually looking back at time series measurements, and merging data from multiple sensors. He was heartened to hear that NEX plans to bring the analysis to the data. The Earth Science community is getting larger; shipping the data to each user is no longer feasible.

<u>High-End Computing Capability</u>

Dr. Tsengdar Lee presented a briefing on HEC capabilities at SMD. SMD is the steward of the agency's HEC capability, and manages two centers. The Ames High-End Computing Center (HECC) is managed by SMD but provides support to all the directorates. Roughly 52% of HECC is allocated to SMD. An additional 5% of peak capacity is held as Agency reserve, and is currently allocated to APD. In FY17 this is a total of 142M standard billing units (SBUs) (throughput measure @$0.24). The NASA Center for Climate Simulation (NCCS) is an ESD-invested computing center, which in FY17 will provide 106M SBUs. NASA has maxed out its current supercomputing facilities; the computing centers are physically full. Year to year growth of HECC utilization has exceeded 50% since 2006.

Under FY17, there total of 454 SMD requests, including 76 new projects. There are a total of 248M SBUs available, thus it is obvious that all requests can't be satisfied. Thus far, 81M SBUs have been allocated for APD, 177M for ESD, 75.5M for HPD, and 31.5M for PSD. Based on the original proportions

allocated to different divisions in 2006, and capacity oversubscriptions, HPD is most oversubscribed at present. Under the FY17 allocation plan, the NCCS remains devoted to Earth science. To spread a little pain, HECC distributed some ESD SBUs to HPD and PSD. The current mitigation strategy is to build a new HECC facility starting in 2018, using a modular computing approach. The planned Modular Supercomputing Facility (MSF) at Ames will use ambient air to cool the system, to save power. No chiller will be required. Power efficiency is 1.06, a highly efficient number. The eventual plan is to make the module 16 times larger, when additional funding is available. In additional mitigation efforts, NASA is now tying HEC needs to the budget planning process. Planning for HEC resources will be required during the proposal evaluation and award process. A bottom-up requirements gathering, top-down allocation model will now be employed. Some other mitigation strategies include: when needed, SMD's divisions will have the flexibility to buy more resources (only when the facility is available); and working with the community through the normal strategic planning process.

In response to a question from Dr. Robinson about the cooling system. Dr. Lee said the temperature at which the system becomes inefficient is 95 degrees F, at which point the facility can use evaporative cooling, which is advantageous in California. Dr. Running added that ambient humidity also will be an indicator of how efficient the system can be. Dr. Peterson noted he had received an informal complaint from WFIRST on getting HEC time for some critical work. Dr. Lee said their request had been received and responded to with a token amount of time. A 2016 module will be made available in December for initial use, and Astrophysics should be getting adequate allocation. Individual projects can be considered separately. Dr. Peterson said he would follow up on his end. Dr. Avery asked Dr. Lee if he knew of any strategic discussions across the agencies for accommodating Earth systems modeling, and getting a large petaflop capacity in one facility for Earth science. Are people thinking about quantum computing, etc. to help the computation load? Dr. Lee noted his role as chair of the Federal HEC Interagency Working Group, and said there are only a few agencies moving aggressively, such as DOE, but not in an Earth science-centric way. Occasionally there are discussions of a facility devoted to Earth science systems; that is a large, difficult problem.

Updates: NASA Science Plan, FACA Committee Charters, Administration Transition

Dr. Jeff Newmark provided information on the NASA Science Plan, which is updated every four years, roughly in line with the Presidential election cycle. The next Science Plan will be issued in Spring 2018; the process has begun. The 2014 Science Plan was very well written, and after a review, NASA is working internally to gather updates for the plan. The SC and full NAC, as well as NAS, will begin to receive drafts for review in the January to March timeframe. The Plan will also receive the approval of the new SMD AA over the next weeks. Ms. Denning noted that the subcommittees will see the drafts first, followed by the SC.

Ms. Denning addressed the chartering of the advisory committees as per the FACA restructuring. The four subcommittees associated with the SMD divisions are becoming stand-alone committees. Their charters were sent to the General Services Administration (GSA) in September, and were approved in mid-October. NASA now is preparing the Federal Register notification that must be published at least 15 days in advance of charter signing, and the committees are expected to be in place within 45 days. Ms. Denning will send out email updates as the process goes forward. Dr. Neal asked how representatives

from the Analysis Groups were factored in. Also, what about the PPS? Ms. Denning said that some groups would be subordinate groups to the FACA committee and she expected the information to flow in a straightforward way directly to the committee. Dr. Newmark expected that the Science Definition Teams (SDTs) and Senior Reviews (SRs) would be subordinate groups and would present their report to the FACA committee rather than directly to the division. Analysis Groups are still to be worked out. Ms. Denning noted that as to the PPS, it is still a subcommittee of the SC, just as the BDTF is still a task force of the SC.

On the transition, Dr. Newmark noted that NASA has prepared a transition binder that will be presented to the landing team after the election. SMD has highlighted missions and the value of integrated science.

Discussion, Findings and Recommendations

The SC considered the BDTF recommendation on a Cloud Computing Demonstration of Exoplanet Pipeline Processing. The purpose of the demonstration would be to free up cycle time. Dr. Peterson heartily endorsed the recommendation as this processing occurs in a serial fashion. Dr. Robinson seconded the endorsement, and the recommendation was unanimously passed. Later in the session, Dr. Gaudi commented on the recommendation's Kepler pipeline issue, saying that since the main Kepler mission is close to close-out, a cloud computing demonstration on the main Kepler mission pipeline might delay close-out and thus be more trouble than it was worth. For TESS, it makes more sense to start from scratch. Dr. Peterson felt that Kepler would have some valuable lessons learned that would make a demo worthwhile. Dr. Holmes said the BDTF really intended its recommendation to be directed toward TESS, as it had already adopted Kepler processing techniques. Dr. Peterson said that he would delete the reference to the Kepler mission before sending it to the NAC, and no objection was heard.

Regarding the BDTF finding "Observing in the Archives", there was unanimous approval.

Regarding the BDTF finding "OCIO-AIST Cloud Computing Initiative" there also was unanimous approval.

The PSS finding on a Mars special regions workshop was intended to address issues sooner rather than later, so the requirements are not moving targets. Dr. Peterson and the SC agreed to pass this along as a finding, and as a topic of discussion with the SMD AA. Dr. Newmark said that NASA was initiating a study with NAS on how planetary protection policy will be informed and adopted.

The PSS finding on the Deep Space Network was to transmit a concern on capability and redundancy, loss of data from deep space missions and a shrinking budget. Dr. Peterson felt that the finding kept the topic on the radar. Dr. Robinson thought that the DSN presentation to SC was overly optimistic given tightening budgets and that there could be a lack of systems backup. The SC agreed to send the finding forward, agreeing that it looks like an accident waiting to happen, and that the committees should keep a robust eye on the problem.

Regarding a HPS finding on a HEC survey across agencies that do R&A, this finding was not brought forward. Dr. Holmes remarked that as the finding is in line with what the BDTF is doing; he would be

happy to take a look at it in coordination with Dr. Lee and report back, and Dr. Lee agreed.

None of the APS findings and recommendations were brought forward.

Dr. Peterson, after reiterating his request for feedback on the FACA restructuring, adjourned the meeting at 5:11pm.

Appendix A
Attendees

NAC Science Committee Members
Bradley Peterson, Ohio State University, *Chair, Science Committee*
Susan Avery, Woods Hole Oceanographic Institution
Jill Dahlburg, Naval Research Laboratory, Chair, Heliophysics Subcommittee
Douglas Duncan, University of Colorado Boulder
Scott Gaudi, Ohio State University, Chair, Astrophysics
Subcommittee James Green, University of Colorado, Boulder
Tamara Jernigan, Lawrence Livermore National Laboratory
Robert Lindberg, Jr., University of Virginia, Chair, Planetary Protection
Subcommittee Clive Neal, University of Notre Dame, Planetary Science Subcommittee
(designee) Mark Robinson, Arizona State University
Steve Running, University of Montana, Chair, Earth Science Subcommittee
Walter Secada, University of Miami
Elaine Denning, NASA Headquarters, *Executive Secretary, Science Committee*

NASA Attendees
Louis M. Barbier
Mariel Borowitz
Marchelle Canright
Lin Chambers
Diane Detroye
Kristen Erickson
Jeff Grossman
Michael Freilich
Gordon Johnston
Amy Kaminski
Tsengdar Lee
Margaret Luce
Christine Mataya
Rebecca McCauley-Rench
Jeffrey Newmark
Adriana Ocampo
Thomas Pittman
Sean Potter
Betsy Pugel
Jonathan Rail
Andrea Razzaghi
Tammy Rowan
Katie Wallace
Cheryl Yuhas
Thomas Zurbuchen

Non-NASA Attendees
Cheryl Achilles, NAS
Francesco Bordi, Aerospace Corp.

Heather Bloemhard, AAS
Stephen Clark, Space Flight Now
Brian Corcoran, U.S. House Science Committee
Dwayne Day, NAS
Vicky Hamilton, Southwest Research Institute
Charles Holmes, Chair, NAC SC Big Data Task Force
Russell Howard, NRL
Gordon Johnston, NAA
Martin Laming, NRL
James Lochner, USRA
Lauren McCarty, U.S.
Senate Conor Moar, Lewis-
Burke Joshua Peek, STSci
Mark Postman, STScl
John Rummel, SETI Institute
William Thomas, American Institute of Physics
Denise Smith, STScl
Marcia Smith, Space Policy Online
Harvey Tananbaum, Smithsonian Astrophysical Observatory

Appendix B
NAC Science Committee Membership

Dr. Bradley Peterson (Chair)
Ohio State University

Dr. Susan Avery
Woods Hole Oceanographic Institution

Dr. Jill Dahlburg
Naval Research Laboratory

Dr. Douglas Duncan
University of Colorado at Boulder

Dr. Bernard Scott Gaudi
The Ohio State University

Dr.James Green
University of Colorado

Dr. Tamara Jernigan
Lawrence Livermore National Laboratory

Dr. Robert E. Lindberg
University of Virginia

Dr. Carle Pieters
Brown University

Dr. MarkS. Robinson
Arizona State University

Dr. Steve Running
University of Montana

Dr. Walter G. Secada
University of Miami

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

Ms. Elaine Denning (Executive Secretary)
NASA Headquarters

Appendix C
Presentations

1. Heliophysics Division Update; *Margaret Luce*
2. Heliophysics Subcommittee Report; *Jill Dahlburg*
3. NAS Extended Missions Study; *Harvey Tananbaum, Victoria Hamilton*
4. Discussion with SMD AA; *Thomas Zurbuchen*
5. STEM Activation Update; *Kristen Erickson*
6. Earth Science Division Update; *Michael Freilich*
7. Earth Science Subcommittee Report; *Steve Running*
8. Planetary Science Subcommittee Report; *Clive Neal*
9. Planetary Science Division Update; *Jonathan Rail*
10. OSIRIS-REx Update; *Jeff Grossman*
11. Planetary Protection Subcommittee Report; *Robert Lindberg*
12. Astrophysics Division Update; *Andrea Razzaghi*
13. Astrophysics Subcommittee Report; *B. Scott Gaudi*
14. Big Data Task Force; *Charles Holmes*
15. High-End Computing Capability; *Tsengdar Lee*
16. Updates: NASA Science Plan, FACA Committee Charters, Administration Transition; *Jeffrey Newmark, Elaine Denning*

Appendix D
Agenda

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

NASA Advisory Council
Science Committee

October 26-27, 2016
Telecon Meeting
(Eastern Standard Time)

Agenda

Wednesday, October 26

1:00 – 1:15	Opening Remarks / Introduction of Members	Ms. Elaine Denning Dr. Bradley Peterson
1:15 – 2:00	HPD Division Update Heliophysics Subcommittee Report	Ms. Margaret Luce Dr. Jill Dahlburg
2:00 – 2:45	NAS Extended Science Missions Study	Dr. Harvey Tananbaum Dr. Victoria Hamilton
2:45 – 3:30	Discussion with SMD AA	Dr. Thomas Zurbuchen
3:30 – 3:45	***BREAK***	
3:45 – 4:30	STEM Activation Update	Ms. Kristen Erickson
4:30 – 5:15	ESD Division Update Earth Science Subcommittee Report	Dr. Michael Freilich Dr. Steve Running
5:15 – 5:45	Discussion	

Thursday, October 27

1:00	Re-open Meeting	Ms. Elaine Denning Dr. Bradley Peterson
1:00 – 2:05	Planetary Science Subcommittee Report PSD Division Update OSIRIS-Rex	Dr. Clive Neal Dr. Jonathan Rall Dr. Jeffrey Grossman
2:05 – 2:15	Planetary Protection Subcommittee Report	Dr. Robert Lindberg
2:15 – 3:00	APD Division Update Astrophysics Subcommittee Report	Ms. Andrea Razzaghi Dr. Scott Gaudi
3:00 – 3:10	***BREAK***	

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

3:10 – 3:15	Public Comment	
3:15 – 4:00	Big Data Task Force	Dr. Charles Holmes
4:00 – 4:30	High-End Computing Capability	Dr. Tsengdar Lee
4:30 – 4:45	Updates: NASA Science Plan, FACA Committee Charters, Administration Transition	Dr. Jeffrey Newmark Ms. Elaine Denning
4:45 – 5:45	Discussion, Findings and Recommendations	
5:45	*ADJOURN*	

Dial-In and WebEx Information

For entire meeting October 26-27, 2016

Dial-In (audio): Dial the USA toll-free conference call number 1-888-790-1716 or toll number 1-212-287-1654 and then enter the numeric participant passcode: 5882231. You must use a touch-tone phone to participate in this meeting.

WebEx (view presentations online): The web link is https://nasa.webex.com, the meeting number is 992 986 313, and the password is SC@Oct2016 (case sensitive).

** All times are Eastern Time **