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MEETING 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. Dr. Peterson opened the meeting, after which Committee members introduced themselves around the table. Let it be noted that the Science Committee had received its annual ethics briefing just prior to the meeting opening.

Discussion with SMD Associate Administrator

Dr. Thomas Zurbuchen, Associate Administrator (AA) for the Science Mission Directorate (SMD), offered remarks on recent events in the SMD. Dr. Zurbuchen reported that he has been visiting various mission teams around the country and is enthusiastic about new directions in research and mission planning. The research he was most interested in tended to be cross-cutting, with many participants that possess grants in multiple disciplinary divisions. SMD's focus on cross-cutting topics and the impacts of research are all connected to NASA's mission statement: discovering the secrets of the Universe (fundamental research; also referred to as expanding knowledge); searching for life elsewhere; and safeguarding and improving life on Earth. The many NASA assets that have been focused on discovering life elsewhere are rushing forward to new discoveries. This current rapid growth we are seeing fits the quintessential s-curve. Since the first exoplanet was announced in 1995, the presence of water on Mars has been observed, as well as subsurface oceans on the Jovian moon, Europa, and the eruption of geysers on Enceladus. These NASA discoveries represent a confluence with research in biology and in neighboring fields, and assuredly researchers will think about these advances differently in the next 10 to 20 years. NASA's role in safeguarding the Earth involves application-motivated fundamental research, and supports space weather forecasting as well as monitoring of hazardous objects. This research also enlarges the space of what we know and asks the hard questions, and can influence well-being on the planet. NASA's research is similar to cancer research, which has many individual aspects that are not necessarily focused on cancer. It is important to remember that entire industries spring from fundamental research. Dr. Zurbuchen held as exemplary science a recent NASA balloon payload, Antarctic Impulsive Transient Antenna (ANITA), launched during the Antarctic summer to study neutrinos interacting with water ice, providing important information about the cosmic ray bombardment of Earth.

Dr. Zurbuchen said he had received much feedback about SMD's research program, and how it affects the majority of scientists who are focused on space science. Research is critical to NASA, which in effect is operating a large science fleet, from assets at the Moon, Lunar Reconnaissance Orbiter (LRO), to the long-lived Voyager spacecraft, still operating in interstellar space nearly 40 years after launch. Voyager is NASA's archetypal story of science success.

Recent mission selections include the Earth Science mission, GeoCARB, a future geostationary carbon cycle observatory. GeoCARB will perform science focused on carbon, measuring fluxes at the appropriate temporal and spatial resolutions. GeoCARB will be sitting on top of a commercial communications satellite, representing a creative way to produce great science. The Mars 2020 Rover mission is going well; its most difficult component thus far has been the robotic arm, which holds the

sample-caching instrument. Mars 2020 is the first step of the Mars Sample Return (MSR) pathway, a top priority of the most recent Planetary Decadal Survey. Efforts continue in identifying the landing site for Mars 2020, which at present is pared down to three possible locations. Some of these landing sites are adjacent to "special regions," areas on the Mars surface that may harbor the temperature and moisture conditions necessary to support life. Another promising mission in development is the Imaging X-ray Polarimetry Explorer (IXPE). X-ray polarimetry is something the community has been trying to achieve for some time. Dr. Zurbuchen described this effort as a "second shot on goal" attempt. IXPE includes an international partnership. The principal investigator (PI) resides at Marshall Space Flight Center (MSFC), and an Italian investigator, associated with CERN science, will provide the sensor.

Two Discovery missions have been selected. Lucy is a mission that will survey Jupiter's Trojan asteroids, using an innovative orbit that will explore 7 bodies. The Trojans are a diverse set of asteroids that may contain some of the early materials of the outer Solar System. Lucy will visit both Lagrange points in the Jovian system. The other Discovery mission is Psyche, a journey to a "metal world." Psyche is an asteroid that has been postulated to be an exposed metal core of a planet. Psyche has two interesting elements: it brings another commercial contractor into deep space, and it will carry a deep space optical communications demonstration package, which will also have a ground-based counterpart. The demonstration is at a cost of $30M and is not necessary for mission success; however, if successful it will change the way NASA does business.

The NASA Transition Authorization Act of 2017 was signed into law in March, the first NASA Authorization bill enacted in 7 years, and it reflects tremendous bipartisan agreement on NASA's goals. The Act advocates for a balanced science portfolio and imposes some significant reporting requirements on SMD, 12 reports in total. Some of these requirements will be accomplished with the aid of the National Academy of Sciences (NAS). The current Continuing Resolution (CR) will expire on April 28. NASA did very well under the President's FY18 Budget Request (PBR). Planetary is proposed for funding at $1.9B (considered to be high for a PBR) and the request proposes funds for a Europa Clipper mission, but not a lander. Earth Science is proposed for funding at $1.8B, with several proposed terminations, including the Earth-observing instruments (Earth Polychromatic Imaging Camera (EPIC) and National Institute of Standards and Technology Advanced Radiometer (NISTAR)) of the Deep Space Climate Observatory (DSCOVR), and termination of the Orbiting Carbon Observatory-3 (OCO-3), Plankton, Aerosol, Cloud, ocean Ecosystem (PACE), and Climate Absolute Radiance and Refractivity Observatory Pathfinder (CLARREO-PF) missions. OCO-3, PACE and CLARREO-PF are in their early phases. The PBR also proposes a reduction in Earth Science research activities. Proposed funding levels for Heliophysics and Astrophysics were not specified in the request. The Office of Education has been proposed for elimination; SMD's STEM Activation activities would not be affected by this proposed elimination. Dr. Mark Robinson asked how Earth Science would mitigate its future losses. Dr. Zurbuchen reported that the Earth Science Division (ESD) has been working on a lot of scenarios, given that Earth science is a systems science that relies on continuous data for systems measurements. ESD still has Suomi-NPP, which could compensate for some PACE measurements, and GeoCARB, which may be able to mitigate the potential loss of OCO-3 data. The budget process will proceed as per usual.

Progress on other fronts: the Neutron star Interior Composition Explorer (NICER) instrument is being loaded into trunk of a SpaceX launch vehicle for delivery to the International Space Station (ISS). The Gravity Recovery and Climate Experiment (GRACE) is going well, as is the development of the Joint Polar Satellite System-1 mission, the first of the next generation of polar-orbiting weather satellites. The Heliophysics Explorer payload Global-scale Observations of the Limb and Disk (GOLD) is currently being integrated onto a communications satellite and is headed toward its launch date in late 2017, and the James Webb Space Telescope (JWST) also continues toward its planned 2018 launch. The Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) mission to Mars is working to its launch window in 2018, and is hitting all key milestones. Asked about NASA contributions to foreign partners' space missions, Dr. Zurbuchen reported that these contributions assuredly exist and could be emphasized more. The Solar Orbiter Collaboration (SOC) with the European Space Agency (ESA), for instance, is making good headway. He said he would be pleased to be asked to show the entire collaborative inventory to the SC in the future. He reported that the recent release of data on the TRAPPIST-1 exoplanet star system was presented in a "TED-talk" version of a NASA press conference, which was 18 minutes long (and not an hour, as is more typical). The discovery and subsequent public engagement shows the power of science to inspire and excite. Close to 50% of the major newspapers featured at the Newseum had the TRAPPIST-1 discovery on their front pages. A paper has been submitted regarding Planet h of the TRAPPIST-1 system, given its location beyond the "snow line." TRAPPIST-1 data have also engendered some papers on atmospheric lines as well as magnetic fields; Dr. Zurbuchen regarded the attention as a "subsonic" wind on exoplanets – not super-sonic as in our solar system - , as it is driving science in areas that have not been explored before. NASA continues to provide great opportunities for discovery. There are 15,000 publications associated with the Hubble Space Telescope (HST) alone. The next major Astrophysics observatory, the Wide Field Infrared Space Telescope (WFIRST), will have a 100-fold capability over the Hubble, and will have tremendous potential in enlarging our understanding of stars and exoplanets.

NASA continues to work to improve the SMD Research and Analysis (R&A) program. For the ROSES call of 2015, there were 4800 proposals received and 1150 selected, for a 24% selection rate. Some questions SMD is considering: Are we supporting innovative/high-risk, open-ended research? Are we cutting off the tail of the curve with the great proposals, along with the bad? Dr. Zurbuchen felt there has to be an "all flowers bloom" aspect to research to accompany some focused questions. He requested that the SC examine the R&A program and provide advice on aspects such as the balance between high-impact versus incremental research, and the mix of interdisciplinary versus focused projects.

Dr. Mihir Desai asked if SMD had anything similar to the NASA Innovative Advanced Concepts (NIAC) program. Dr. Zurbuchen noted that NASA has vehicles for this type of award, but the question remains: is it adequate? He also noted that he had culled much feedback from many good people on the subject of R&A, and had asked a colleague to summarize everything into 10 questions. He then picked the three most relevant questions for the SC to consider.

Dr. Zurbuchen addressed the recent introduction of NASA's internal scientist funding model, the result of an Agency decision to look at how it funds approximately one thousand of its civil servants who contribute widely to Agency missions as program/ project scientists, instrument scientists, mission

planners, scientific data archivists/ analysts, and leading researchers in their fields. A funding model on how to carry this out has already been developed. All research will be peer-reviewed, and there is to be no change of balance of funds with respect to those spent outside and inside NASA. The model is looking at critically sized teams (not one and two person projects as with university-funded PIs) and at ways to fund them under some directed funds. As an example, there are heliophysics civil servant scientists at the Goddard Space Flight Center (GSFC), the vast majority of whom receive their funding through missions. But there are also some who are competing for every single dollar. There are some elements of missions and projects that would benefit from critically sized teams. NASA wants to enable the external science community, rather than compete with it. Dr. Zurbuchen stressed that everyone should understand this is version 1.0 of the funding model. NASA is looking for a win-win with this approach and felt it important that the SC be made aware of it. He felt it would make the whole science community better. The new model has been presented and discussed at virtually every NASA Town Hall meeting at recent professional conferences.

Dr. Carlé Pieters commented that the model should be carefully monitored to make sure it does not create problems elsewhere. Dr. Zurbuchen noted that NASA had worked hard at looking at the model holistically. Dr. Peterson asked what sort of resources these civil servants might request under the new model— for example, there is the Community Coordinated Modeling Center (CCMC) at GSFC, which enables civil servants in Heliophysics to write a proposal, after which NASA directs money to a certain level that gets negotiated and peer-reviewed for an activity at CCMC. Dr. Robinson commented that the balance of missions he had observed in Dr. Zurbuchen's charts was striking; there were very few missions targeted at Venus, Mercury, or the Moon, while Mars had seven active missions and three more on the way. Dr. Zurbuchen countered that 80 percent of this question is determined by the Decadal Surveys, which has prioritized Mars repeatedly. However, there are priorities at the Moon that NASA is talking about right now. Dr. Pieters noted that all the medium and small cost missions were not prioritized, only the big ticket items were, which seems to fuel a circular discussion. Dr. Zurbuchen responded that NASA selects PI-class missions based on science excellence, not the strategic overlay, and felt the Decadal Survey was correct in staying away from the smaller missions. Dr. Douglas Duncan commented that SMD STEM Activation is doing something radical (and welcome); i.e., for the funded PIs, NASA is insisting on cooperation, rather than competition. GSFC and the Jet Propulsion Laboratory (JPL) have great imaging laboratories, and PIs are now being urged to work with them to maximize dollars. Dr. Douglas felt this strategy had been surprisingly effective. Dr. Walter Secada asked what NASA was internally and uniquely positioned to do with respect to civil servants in its new internal funding model. Where are the meeting points for a grand synthesis? For example, how might it emulate working with mathematicians, oceanographers, and basic physicists modeling the flow of carbon beneath the ocean surface? Dr. Zurbuchen replied that this will depend on the community, which will change over time as capabilities grow or disappear. Part of the strength is to create overlap in constructive areas, and to make compromises between efficiency and effectiveness. Dr. Susan Avery commented that NASA should ensure that it continues to be a place to build and maintain a fruitful science career. Dr. Zurbuchen said he was most worried about building the workforce of the future, to produce scientists who were capable and excited to tackle the challenging science of the future. NASA is working and thinking hard about this very high priority.

TRAPPIST-1 Exoplanets

Dr. Nikole Lewis of the Space Telescope Science Institute presented a briefing on the newly discovered TRAPPIST-1 exoplanet system, 12 parsecs from the Earth. She reported having been part of the innovative February 22 press conference, at which the completely unexpected discovery of 7 Earth-sized planets had been announced. This system spurred the imagination of the science community and the general public. The news conference reached half the people in the world, 3 to 4 times the usual press coverage. The TRAPPIST-1 system will help to answer questions on the origins and the possibly extant nature of life, as well as on planet formation, chemistry, atmospheres, and the nature of biospheres. Can we detect life if it exists elsewhere? A multidisciplinary approach is needed to paint a complete picture of these planets.

The TRAPPIST-1 exoplanets span a wide range of characteristics: they have anywhere from 1.5-day to 20-day orbital periods, and radii from 0.7 Earth radii ($R_{earth.}$) to 1.13. All of these planets were discovered by the transit method, and all 7 planets transit their host star, as seen from Earth. The system is named after the instruments that discovered them (TRAnsiting Planets and Planetesimals Small Telescopes). Their existence was confirmed with the use of the Spitzer telescope (500 hours), which saw some double and triple transits that complicated early interpretations. Spitzer followed up on the TRAPPIST observations and stared at the system for 22.5 days to provide long-baseline, stable photometry. During this time flares were also observed. The TRAPPIST-1 star is bright at infrared wavelengths, and is a type M8 dwarf. The signals studied represented a half- percent to one-percent transit for most of these planets. These signals are on par with what was being received from Jupiter hot stars via HST in the mid-2000s. These are relatively strong transit signals. Stellar type determines the location of the habitable zone; it is thought that these planets are likely tidally locked with their host star. Dr. Pieters asked whether the determination of habitable zones includes the length of time over which they actually exist. Dr. Lewis said that Ramses-Ramirez has done work on this question, which will need to consider the co-evolution of the orbital periods. Planets e, f, and g are in the traditional habitable zone, while Planet d is in an extended habitable zone. Planet h could be in there too if it has a significant amount of hydrogen. Even Planets b and c might have permanent night sides that contain liquid water on the surface. With close proximity to the star, space weather also has a great impact, as this subjects the planetary surfaces to extreme ultraviolet flux. The Kepler/K2 telescopic system just completed an 88-day-long stare, the results of which were released on March 8, with the first paper coming out on March 13; many (potentially life-ending) flares occurred during the observation period. K2 has a broadband visible filter and provided some data on stellar rotation periods and stellar age refinement, now estimated at 3-8Gyr. The orbital period for Planet h has been constrained to 18.764 days. Radio observations are being done now that will determine magnetic field strengths.

Further exploration of the TRAPPIST-1 planets will allow comparative planetology through the use of high-precision infrared spectrophotometry. These data will allow measurement of masses and observations of frequent deep transit events. Eventually the planet masses can be derived from transit-timing variations (TTVs). Probing transiting planets allows us to see thermal radiation and reflected light from the planets as they appear and disappear; and to see cyclical variations in brightness of planet (the best way to determine whether it has an atmosphere). Dr. Duncan and Dr. Scott Gaudi both noted that some of the assets used to watch the TRAPPIST-1 system were not thought capable of doing some of the

finer/deeper aspects of the observations. Dr. Lewis added that HST has begun atmospheric reconnaissance work using the Wide Field Camera 3 (WFC3) infrared prism, and is looking at the combined atmospheres of Planets b and c, looking for hydrogen and water. This data will constitute important guidance for future JWST searches. The other part of the research is looking at Lyman-alpha lines. TRAPPIST-1 is one of the coldest M stars to date for which these lines have been detected. The data indicate that there may be hydrogen escaping from the planets, possibly due to water reservoirs on the surface. K2 data are still being analyzed and Spitzer just completed a second 500-hour stare. SPECULOOS (Search for habitable Planets EClipsing ULtra cOOl Stars) is soon coming on line to collect more relevant data, and the bulk density of these planets will soon be very well known (within 15%). The importance of TRAPPIST-1 is that if there are Earth-sized planets around stars with relatively large signal strength, they can be used as "training wheels" for JWST. About 30 to 60 transits are needed to constrain (not detect) ozone. Dr. Peterson asked why this star in particular had been the subject of observation. Dr. Lewis replied that this group had been looking at brown dwarfs with possibly habitable planets, and was looking for stars that opened up opportunities to observe for longer periods. Dr. Duncan commented that with such a small star, one could do similar work with tiny telescopes. Dr. Peterson noted that there are no M-type dwarfs visible to the naked eye, implying that there are many more possible TRAPPIST-1-like systems to be discovered.

Earth Science Subcommittee Update

Dr. Steve Running, Chair of the Earth Science Subcommittee (ESS), gave a report stemming from its January 2017 meeting. He remarked that he was envious of planetary science, given the endless avalanche of recent negative press for Earth science. He said that in his hundreds of public talks, he always endeavored to point out how thin Earth's atmosphere truly is, at only about 10 miles deep, to give the perspective of Earth volume relative to the atmosphere.

The constellation of Earth science satellites, starting with Terra and Aqua, has taken many years of planning. It took 17 years and 19 years of planning to launch Terra and Aqua, respectively. These missions were quite successful and operating well. ESD is now working with smaller satellites, with 5- or 6-year planning horizons, and smaller platforms that go up more regularly than in the past. He noted that the Indian Space Research Organisation (ISRO) launched 100 microsatellites with just one launch. It is the dream -- to see all of Earth, all of the time, in multiple wavelengths, in order to adequately study the Earth system.

ESS has been reconstituted as the Earth Science Advisory Committee (ESAC) under the new Federal Advisory Committee Act (FACA) structure. Dr. Running was pleased that now there will be the ability to directly advise the ESD Division Director. Based on the most recent ESS discussion with ESD Division Director Dr. Mike Freilich, ESS thinks that ESD has a good winning streak going, given its many missions and mission successes. At the January meeting, ESS spent particular time on small satellites and coordinated launches as well as satellite constellations. ESS issued a specific finding on these constellations that are demonstrating successful implementation in all 4 ESD areas, and holding promise for a broad mission portfolio at relatively low cost. ESS also heard a briefing on the Earth Science Technology Office (ESTO), which manages 120 active technology projects, on average, and issued a finding on the importance of cubesats, which supported the continued effort of the ESD Technology

Program for advancing miniaturization of instruments, among other technology development activities. ESS also issued findings on the CubeSat Launch Initiative (CSLI), Venture Class Launch Services (VCLS), and the potentially cost-efficient strategy of the Small Satellite Constellation Initiative (SSCI), a proposal to buy data from commercial satellites that has not yet been approved.

ESS issued a recommendation to continue the Satellite Needs Working Group (SNWG) to maintain interagency dialogue; Dr. Running noted that many of the agencies in SNWG involved don't even know what is possible, or what NASA is capable of doing. ESS also recommended that ESD formulate a new template for the division's annual Government Performance and Responsibility Modernization Act (GPRAMA) exercise, and noted the committee's eagerness to help program managers put together the relevant documentation. Dr. Peterson felt the other advisory committees may find the new template useful, and that this recommendation was a good thing to pass forward. ESS also issued a finding on the utility of reporting out the socioeconomic implications of improved Earth observations from space. Dr. Secada took the long view on this concept, and felt that the SC should probably think about this finding as indicative of future products that might be offered to the Federal agencies. Dr. Running thought there was a thread of methodology that would be defensible, and supported further consideration of ESS's January briefing on socioeconomic value of Earth science, which had been based on peer-reviewed papers written by both economists and Earth scientists.

Dr. Running noted that Earth science is on the cusp of its next Decadal Survey, due in December of this year. Dr. Avery supported ESS's recommendation on the SSCI data buy, but felt it important to have standards put in place ahead of time; these standards need to be equal or better to be able to support science. Dr. Running agreed, adding that a good example can be found in commercially available high spatial resolution data sets, which typically have poor spectral resolution. Dr. Avery said the other issue is the dependency of other Federal agencies on NASA, which illustrates sharply the fact that NASA needs to maintain its expertise. Another socioeconomic issue is the value of the impact of science discovery and fundamental research, which must be recognized. Dr. Running reiterated the importance of defining a broader analysis of the systems engineering impacts used to determine socioeconomic benefits. Dr. Tamara Jernigan felt the socioeconomic argument was a good offensive play, to demonstrate the value of Earth science upfront. Dr. Duncan agreed, adding that it is important to realize that the broader impacts of Earth science are not being recognized because people don't actually know the real capabilities of NASA's Earth Science program.

Joint Agency Satellite Division

Joint Agency Satellite Division (JASD) Director, Ms. Sandra Smalley, presented a status. JASD resides within the SMD, where it utilizes NASA's expertise in building satellites and ground systems, launches and commissions them, and then hands them off to the operator, the National Oceanic and Atmospheric Administration (NOAA). JASD is supporting JPSS, the Geostationary Operational Environmental Satellite-R series (GOES)-R, DSCOVR, JPSS Ground, and Suomi-National Polar Partnership (SNPP). GOES-R, now known as GOES-16, was just recently launched. The GOES-R series carries 6 instruments, and there are 4 copies of each. All GOES-16 instruments have now been turned on and they are working well for the most part. The data should be operational, and be in widespread use by the forecasting community by November. The handover to NOAA will take place in June. Thus far, the mission has

encountered one issue with a magnetometer, which is not currently meeting requirements and probably will not, due to unexpected thermal-electric effects. JASD is trying to understand the root cause. GOES-16 will revolutionize weather monitoring, providing a 3-fold increase in spectrum and a 4-fold increase in resolution. The Advanced Baseline Imager (ABI) instrument can see additional water vapor bands, and can also better characterize the amount of moisture in the atmosphere, as well as track wildfires more capably (both hot spots and smoke plumes). ABI also makes possible a day/night band city lights database, using ABI Imagery over Visible Infrared Imaging Radiometer Suite (VIIRS) data. Another new GOES-R product is the Geostationary Lightning Mapper (GLM), which displays lightning strikes at 25 frames per second. The GLM will improve forecasting of tornadoes, among other storm features. The GLM will also help to image storms over oceans, where radar is not available to do so. GOES-R also carries a space weather suite, the Solar Ultra Violet Imager, which can see filaments, holes, etc. on the solar surface that may presage coronal mass ejections and the subsequent radiation hazard to humans on ISS, as well as interference with communications and power grids. Asked by Dr. Running if commercial weather forecasters were using GOES-R data yet, Ms. Smalley advised that the data are not yet operational, but provisional.

JPSS, a polar satellite series that is critical to 7-day forecasting, is making good progress. The series is comprised of 4 satellites, all in the same polar orbit, spaced apart. An initial JPSS-1 thermal vacuum test was completed in October 2016, whereupon issues with two instruments (Advanced Technology Microwave Sounder and Spacecraft Control Processor-2) were discovered and repaired. An overpainting issue with JPSS-2, traced to a personnel problem on the contractor side, is being corrected. Ms. Smalley displayed imagery from SNPP showing an eruption of Pavlof volcano on the Aleutian Peninsula; in this instance, SNPP provided timely and accurate guidance for re-routing aircraft in the ash plume's path. SNPP also provided imagery of the September 2016 Soberanes Fire (California), that proved helpful to real-time emergency planning, and the monitoring of concerns afterward (e.g. flooding, landslides in denuded regions). SNPP also helped firefighters plan emergency response during the Canyon Creek fire of 2015. A new satellite project, MetOp C, is now being developed in a partnership between NOAA and ESA. The satellite will measure temperature and humidity from Earth's surface to the stratosphere, and is scheduled to launch in 2018.

In 2016-17, NASA and NOAA requested an independent review of the National Environmental Satellite, Data, and Information Service (NESDIS). The NESDIS Independent Review Team, led by Mr. Tom Young, essentially gave kudos to the NOAA/NASA partnership, regarding it as critically important to life and property, national security, economy, and quality of life on Earth. JPSS governance, robustness and potential gap mitigation are continuing concerns; NASA and NOAA are working to mitigate and streamline governance and address the concerns of the review team. The team found in particular that future space and associated ground systems must be robust with a "two failures to a gap" criterion, and must provide equal or better weather forecasting and severe storm monitoring performance. In addition, NESDIS must look holistically at systems engineering from early design through satellite deployment. Dr. Running commented that back in the National Polar-orbiting Operational Environmental Satellite System (NPOESS)-planning era, it became clear that NOAA's main customer was the weather forecasting community, which is very different from NASA's whole-Earth science community. The science community was concerned that NOAA didn't understand this distinction. Ms. Smalley felt she

could state positively that NOAA recognizes the size and composition of its community. JPSS is certainly looking at the broader community. Dr. Pieters asked about JASD's path through the economy. Ms. Smalley reported that NASA and NOAA have been querying the emerging commercial market, and have found much data that is freely available. Dr. Avery commented that if the weather enterprise goes to a commercial entity, since forecasting is so important, NASA can't assume that commercial providers have better data; the other key point to JPSS is the issue of the relationship of NASA and NOAA. Ms. Smalley agreed that sometimes NASA must act as a partner, and sometimes a contractor.

FACA Committee Charters Update

Dr. Jeff Newmark reported on the progress of the new FACA chartering of four new stand-alone advisory committees for SMD. These are now the Planetary Advisory Committee (PAC), Astrophysics Advisory Committee (APAC), Heliophysics Advisory Committee (HPAC), and Earth Science Advisory Committee (ESAC). The committees will be reporting directly to the division directors of SMD, who will then be obligated to provide a written response to the committees' recommendations. This structural change was brought about to enable findings and recommendations to be more directly targeted to the division directors, without having to vet the advice up and down the NAC hierarchy. It is hoped that the change will engender closer dialogue between the experts and the divisions, allowing the SC to focus on larger questions. Community-based studies such as Senior Reviews and Science Definition Teams now will be subcommittees, with terms of reference (TORs) formulated by the committees. These new subcommittees will report back to each division committee. Any cross-cutting or high interest topics will be identified and brought up through the committee to the SC.

The committees have been stood up and chartered, and members and chairs are being appointed. Maintenance of expertise and diversity in all dimensions will continue to be the primary goals in regard to committee membership. New outreach is being conducted at the Lunar and Planetary Science Conference (LPSC) to recruit candidates for the PAC. Senior Reviews for ESAC and HPAC are currently being formed. A meeting of the APAC has been scheduled for April 24-25 at NASA Headquarters. Dr. Pieters asked if the committee issues had to be taken to the director and to the NAC. Dr. Newmark explained that such decisions are determined within each committee. Dr. Running, remarking upon his impending retirement after 4 years of service as Chair of the ESS, said he welcomed the change, which would help to remove topics that did not require the attention of the SC. Dr. Peterson reminded the subdiscipline committee Chairs to continue to pass findings and recommendations to the SC that might be helpful to all the committees. Ms. Denning noted that relatedly, the SC would continue to hear from the division directors, but that the presentations would be briefer. Dr. Peterson noted that the SC was planning to hear in-depth reports from each division director once per year, however, divisions would retain the opportunity to bring forward urgent topics.

Other Updates from Committee Chairs

There were no reports.

Discussion

Members discussed various science nuggets pertinent to their disciplines. Dr. Duncan shared some URLs on the summer 2017 eclipse, displaying an excellent 4-minute public service video. He noted that there is

a persistent and dangerous misconception in the public that one can view a solar eclipse with sunglasses (this would actually require 5000 layers of sunglass lens material). The video and more information on the solar eclipse can be found at http://www.colorado.edu/eclipse. Dr. Duncan also has arranged to distribute boxes of eclipse-viewing sunshades to 2000 libraries across the nation. Anyone can obtain these eclipse glasses for free from these participating libraries. He mentioned the impending publication of a book on the subject of the 1878 eclipse, which was notably observed by Thomas Edison.

Ms. Denning announced an event on April 13 at 2:00 p.m. in the James Webb Auditorium at NASA Headquarters on the subject of new discoveries that will inform the Oceans Beyond Earth theme of planetary exploration, relating to the future Europa Clipper mission.

Public Comment Period
No comments were recorded.

Deep Space Network
Mr. Pete Vrotsos reported on the Space Communications and Navigation (SCaN) response to a NAC request to report on data transmission issues in the Deep Space Network (DSN). Responding to anecdotes about data dropouts at the Canberra and Madrid facilities, particularly during science missions, the SCaN program compiled statistics on unscheduled downtime to differentiate events occurring due to weather, mechanical, and other operational issues. Unscheduled downtime by definition refers to those events caused by: weather; other DSN-related faults (airspace emergency, external communication failure, etc.); hardware and maintenance-related failures (MRFs); and other. SCaN found that for fiscal years 2012-2017, downtime and data losses were largely due to hardware and MRFs, occurring usually in the oldest assets. Over time, DSN has responded to data loss events by focusing on transmitters, which drive the majority of failures. DSN mines its documents and failure logs for information, to determine whether the number of failures are proportional to the age of the asset. Mr. Vrotsos pointed out that about 8-15% of the time, there are in fact no targets to point to. The DSN now has an app that shows the activity of all three stations, as well as every asset (https://eyes.nasa.gov/dsn/dsn.html). He noted that historically, the missions want the 70m dishes, but they don't necessarily need it. DSN is trying to react to this demand by using other assets.

Planned major downtimes for 2016-22 are already documented and do take into account mission timeline and critical events. Downtimes tracked by the DSN at JPL can be found at https://rapweb.jpl.nasa.gov/Downtime.html. These scheduled downtimes are worked well in advance with the mission communities; Mr. Vrotsos was not sure how well this fact gets communicated to the PIs at large. Asked whether there were plans to retain the 70m capability beyond 2022, Mr. Vrotsos indicated that the plan is to maintain them at least through 2030. There will be a 70m dish in Spain, and additional antennae will be installed at Goldstone and Canberra in the 2020s. Dr. Robinson asked if the budget was sufficient for maintenance. Mr. Vrotsos estimated that the budget is at a level one would not want to go below, with respect to maintenance at this point. The budget is adequate, but not generous. If SCaN sees indicators of something amiss, it addresses them. SCaN maintains 13 assets; in the annual scheme of things, someone or something is going to get a miss. Spacecraft emergencies are prioritized above all other activities – the rest is prioritized through the missions. Dr. Jeffrey Hayes added that the priorities are

always addressed intramurally, and that SCaN would benefit from receiving a list of what SMD thinks the most prioritized assets are, to at least a broad-brush order.

Big Data Task Force

Dr. Charles Holmes presented the fourth report of the SC's Ad Hoc Big Data Task Force (BDTF). The BDTF has applied for one additional member, which has been held up by the transition. The agenda for the fourth meeting included a briefing from the SMD AA, and the BDTF was pleased to hear that Dr. Zurbuchen has requested an NAS study on how one can archive results from model runs. NASA's CCMC has a 10-year-old model archiving system that could perhaps be extended with some further study. BDTF also had a briefing from Dr. Josh Peek, who provided highlights from the astronomy workshop "Detecting the Unexpected." Dr. Holmes noted he had not seen adequate representation of NASA at this workshop. He noticed this also at some other related workshops. Dr. Holmes reported that Drs. John Sprague and Tsengdar Lee have begun an internal Big Data Working Group (BDWG), mainly of Chief Information Office (CIO) assets, and other engineering assets that are working on the problems of capturing all sorts of NASA data. BDWG holds annual workshops; BDTF member Dr. Ray Walker is scheduled to attend one at JPL. BDTF also had a panel session with the SMD program officers who preside over NASA data archives, to exchange feedback and ideas. Dr. Dan Crichton, the new Data Science Mission Office director at JPL, also gave a brief report. BDTF will visit JPL in October to learn more about the office. BDTF is also working on a white paper on four topics, and moved this effort along during the course of the meeting.

Dr. Holmes presented an interim report of the BDTF to SMD in November, briefing the SMD AA, division chiefs, and the program officers for data and computing; he reported receiving good feedback. The interim report identified some trends and common themes that BDTF wishes to flesh out with time. In particular, the Earth System Data and Information System (ESDIS) Cloud Evolution Project, a 12-month effort to evaluate commercial cloud technologies for foundational EOSDIS business and technical capabilities, is of great interest. The project runs from September 2016 to September 2017. BDTF feels this is an exciting project that will help to clarify a business case for storing some of NASA's archival science data on commercial cloud services, especially in light of the flux and evolution of fee structures. Across the industry, the fee structure is being revised such that it might become a more attractive option for NASA.

BDTF has been examining NSF's Big Data Regional Innovation Hubs project, which covers 50 states and has commitments from more than 250 organizations. The question is whether this project is something in which NASA should become involved. NSF's portfolio of programs is designed to bring together domain scientists, computer scientists, applied mathematicians and end users to use data to solve a variety of scientific, engineering, and social challenges. BDTF feels that it would be valuable for NASA to participate in the Regional Hubs and Spokes project; a recommendation will probably be issued at the next BDTF meeting. Another worthwhile subject for NASA to contemplate is the Pacific Research Platform, which is creating a big data "superhighway". BDTF member Dr. Walker has tested high-speed networks between Ames Research Center and UCLA, and recently achieved 12Gbps data transmission rates, with improvements expected. These are impressive results despite very few resources expended. BDTF plans to recommend that SMD tie into this high-speed network as it expands across the country.

BDTF also heard a briefing about a Department of Energy (DOE) Exascale Computing project, a holistic approach for delivering advanced architecture and capable exascale supercomputing. The project will not build the computer itself, but will lay out the groundwork over a 5- to 7-year timeframe, after which contracts will be issued. DOE has asked NASA for input into exascale applications in the areas of climate action, greenhouse gases, and other relevant disciplines. BDTF plans to recommend that NASA participate in this project.

NASA has increased its high-end computing (HEC) capacity at Ames Research Center by 42% over the last calendar year. There had been a major issue with oversubscription, which is now expected to improve. The application support team recently used magnetohydrodynamic (MHD) code to simulate black holes, resulting in speedier input/output and significant improvements in efficiency. BDTF issued a finding on this.

The Science Committee received a request from the Heliophysics Subcommittee in October 2016 to perform a quick survey on HEC systems across the Federal agencies: Department of Defense (DOD), DOE, NSF, etc. Dr. Tsengdar Lee, the SMD program executive for HEC, conducted the survey and report preliminary results to the BDTF. The survey found even worse oversubscription rates at other agencies when compared to NASA, a surprising story that is still developing.

Dr. Holmes briefly described the BDTF schedule for 2017, which will include a June/July teleconference, a visit to JPL in late October, and a December meeting to finalize its report. Dr. Holmes said he was applying for a session under the Earth and Space Science Informatics (ESSI) section at the AGU meeting. The task force will finalize several recommendations on progress in the SMD Data Science Program, SMD's Data Archive projects, and NASA's part in NSF's Big Data project.

Dr. Secada asked if commercial applications for cloud might be used for archiving. Dr. Holmes replied that yes, BDTF could recommend the use of commercial cloud strictly for storage of archival data. The issue is to look at fixes to improve throughput, however, and not only cost. He agreed that performance will be very important to the decision. Dr. Robinson asked, with respect to application program interfaces, about who would create the interfaces for large data sets, and determine how to get the data out. Dr. Holmes replied that data reduction in the vicinity of the data storage itself is recommended; this will be covered in BDTF's study of data analytics (server-side analytics). Dr. Running asked if BDTF had considered the longevity (in decades) of commercial cloud storage capabilities. Dr. Holmes said not yet, but it is certainly on the agenda to think about. Commercial vendors have many customers that will need long-term preservation. BDTF will continue relevant discussions on the topic.

SC reviewed the main BDTF finding, and moved it to the next day for adoption. Dr. Jernigan asked whether DOE's exascale project intersects with NASA's computational efforts in any way. Dr. Holmes noted that this occurs only if NASA is part of a research team at DOE. However, DOE is looking at the exascale project as a national asset; that's why BDTF supports NASA effort to send their codes and data problems to the project.

Discussion

Dr. Peterson raised concerns about the new Internal Scientist Funding Model, as it was not clear to him what the current model actually was, or how NASA intends to change it. Dr. Jernigan noted that at Lawrence Livermore National Laboratory (LLNL), every project gets taxed, and those dollars go to long-term internal basic research. Several members aired similar concerns about clarification. Dr. Holmes felt that full-cost accounting never quite worked due to NASA's inability to establish overhead accounts. Dr. Kathryn Flanagan commented that it seems almost necessary to impose a set-aside for large programs because competition drives the selection of smaller missions. High-risk, high-reward science might be served better by an internal set-aside. Dr. Secada felt that NASA program officers tended to take more risks in the past; there is much decrying of conservatism. The Committee generally agreed that constrained resources remained the bête noire fueling the problem.

April 13, 2017

Re-open Meeting

Ms. Denning re-opened the meeting. Dr. Peterson began the proceedings with introductions around the room.

Science Committee Retool Discussion

Dr. Peterson addressed the changing functions of the Science Committee with respect to the workings of the former subcommittees, which will henceforth function as separate entities. Ms. Denning presented the Terms of Reference of the SC, with a focus on broad scope and responsibilities. She noted that the Committee had received specific direction from the SMD AA to provide advice on matters that require the most input, and emphasize SC's valuable characteristics for the greatest impact. Nuts and bolts discussions are what are most needed. Henceforth, SC will focus on developing findings and recommendations on cross-cutting issues, and schedule more time for problem-solving sessions and updates. Briefings will have a reduced amount of time on each agenda, and each SMD division will present a deep status report once per year. The SC is also adding an outbriefing to the SMD AA as part of its regular agenda. The Committee is looking forward to its joint summer meeting (July) with the Human Exploration and Operations Committee of the NAC. Ms. Denning asked SC members to contribute further thoughts.

Dr. Robinson asked if the reorganization would address what wasn't working right. Ms. Denning cited the typically onerous passage of findings and recommendations; divisions weren't getting all of them through to the end, and the process was lengthy and cumbersome. The new structure will free up the SC to focus on cross-cutting issues. Briefings are taking up too much time as well, because slides can be easily read in advance of the meetings. There was dissatisfaction from both agency staff and advisory committee members with the inefficiency of the old process. Dr. Peterson remarked with regard to the in-depth briefings at every meeting, that things don't change much over 3 or 4 months. One goal was to cut down the amount of work done by the divisions to present so frequently. Dr. Jernigan commented that the DOE Office of Science does this sort of thing well; it forms subcommittees to answer charges, much like NAS. Dr. Peterson felt that the analysis groups such as the Program Analysis Groups (PAGs) and Study Analysis Groups (SAGs), finite groups answering specific questions, functioned well; as did the Science

Interest Groups (SIGs), indefinite groups that advanced a topical area (e.g., far infrared). Ms. Denning noted that the SC can always form subcommittees to function like the PAGs, or task forces. She further noted that the SMD AA is requesting that the SC look at innovative technology and experimentalism, and the SC does have an at-large seat on technology. The SC can also have an interaction with the Science and Technology Mission Directorate (STMD) advisory committee, the NAC Technology, Innovation and Engineering Committee (TI&EC). Technologies can also be assessed through subcommittees or SAGs.

Dr. Avery was curious as to whether the SC could be strategic or not. Ms. Denning felt the Committee could be strategic on a more short-term and tactical basis. Dr. Peterson noted that the Decadal Survey would continue to provide the overall strategy for NASA. Dr. Avery commented that NOAA's Science Advisory Board, to avoid getting bogged down in minutiae, focuses on new technologies, revolutionary and disruptive ideas, and across-the-board strategic thinking; she wondered if the SC can do the same. Dr. Peterson reminded members that they all set the agenda collectively, and must take charge of the Committee's direction. Dr. Robinson asked what distinguished the SC from the individual divisional advisory committees. Ms. Denning answered that it was basically scope; the division committees focus on each division and provide advice and communicating directly to the division directors, while the Science Committee advises NASA and the SMD AA on a broad scope of cross-cutting issues. Dr. Newmark felt the structure makes the committees more tactical for the divisions. Dr. Gaudi agreed, noting that APS had talked a lot about R&A, which affected all of SMD, and which was a topic that typifies an issue suitable for the SC's deliberation. Ms. Denning added that SC should be a strategic arm, tackle particular questions, and emphasize how SMD should do business rather than why. Ms. Denning noted that the SC can also hold non-public FACA meetings for the initial drafting of analyses, but stressed that full discussions, and deliberations and voting on findings and recommendations must be conducted publicly, under FACA rules.

Research and Analysis Improvement

Dr. Max Bernstein briefed the SC on changes in the SMD Research and Analysis (R&A) program, and addressed the question of how SMD could improve the program. Are there ways to be more efficient and push the state-of-the art forward, faster? How can SMD ensure that programs are tackling the most important problems? These questions are of great interest to the new SMD AA. Dr. Bernstein requested that SC provide feedback on how to do this, after which SMD would generate an official "charge." The SC, consulting with the advisory committees, will then respond to the charge, possibly at the July Science Committee meeting.

Questions of note:

Are we appropriately handling, soliciting and funding: Evolutionary vs. revolutionary projects? Focused vs. interdisciplinary projects? Are we encouraging productivity and making the best use of the community? Are there aspects of how we solicit (many calls vs. fewer open-ended ones?) and review proposals that could be more supportive of R&A goals? What are we missing? Potential factors of interest include high risk/high payoff projects; award duration; the scope of the ROSES Program Elements; proposal page length; focus on early career investigators; and evaluation criteria and scoring. Regarding high risk/high payoff proposals, SMD has not yet tried to track whether these proposals are selected at a higher rate than more incremental proposals. It might be worthwhile to assign such proposals to Category

III status (a short study aimed at proving a new technique). Should there be a separate call for this type of thing? Interdisciplinary projects could give a strength for inclusion of funded tasks, for example, to bridge between observations, laboratory measurements, and theory; however, these proposals make take greater care to review. As to award duration, the default has been 3 years. Even when 5 years was allowed, 3 years seemed to be a "magic number." Dr. Peterson felt 3 years was a good duration for the funding of graduate students and post-docs. Dr. Bernstein asked: do we want longer award duration, at the expense of making the program less flexible? Larger award size and duration may be at least conducive to supporting interdisciplinary work and higher-risk projects. He referred to the "submarine" chemistry that sometimes gets accomplished in long-duration awards; these are little preliminary experiments performed while thinking only about science, and not worrying whether the work is in the scope of the award.

When there are more ROSES program elements in a division (e.g., Appendix A), there are more "edges" between the calls. In divisions with fewer calls, the calls tend to be broader in scope. If there are interdisciplinary topics that are not happening, ROSES calls can be re-tooled to accommodate them. Most ROSES program elements allow 15-page proposals, and a single page length may put (presumably more complex) interdisciplinary proposals at a disadvantage. The K2 guest observer program was given as an example of a call that has two different page limits (and budgets) for "large" and "small" projects, in an attempt to compensate. The more uniform a program is, the easier it is to allow this kind of variation. What works for a relatively uniform program such as K2, however, may not work for a more diverse call. Due dates are another issue: NSF has a program that has no fixed due dates, and they claim the number of proposals goes down as a result. SMD uses rolling submissions for a few programs, such as TWSC and Rapid Response and Novel Research in Earth Science, but generally this is not done. Should SMD R&A move to no fixed due date?

Dr. Robinson remarked that it seems like NASA has a long history of doing R&A in different ways: is there any experience base that indicates what works? Dr. Bernstein noted that SMD is responding to specific questions from the SMD AA, who is trying to understand how R&A works. In addition, Dr. Bernstein felt there was value in getting advice outside of the Agency on these things. PSD is about to get a report from NAS on their R&A restructuring, and the SC can also consider the results in that report. The adoption of the two-step proposal submission process and the creation of the Planetary Data Archiving, Restoration, and Tools (PDART) program were results of restructuring, which had revealed there was data out there that needed to be archived, or transformed into a higher-order data product, hence the development of PDART.

Most SC members and some NASA staff agreed that funding was the fundamental issue, and Dr. Bernstein felt this was especially true of Heliophysics. Dr. Newmark felt that the R&A program touches most community members, and reported having heard from them a perception of barriers to achieving best amount of science per dollar. Perhaps Headquarters is not enabling the community to do the best science possible. The SMD AA is putting this question to the community. Dr. Jernigan noted that the low-cost access to space (LCAS) program in Heliophysics was a worthy effort. Dr. Gaudi tracked back to the funding problem; he truly thinks the basic problem is not enough science funding. Efforts in understanding the cause of the low selection rates in Astrophysics research revealed only that everyone had a pet theory for the cause of the low selection rates, all of which were subsequently shown to be

incorrect. Dr. Peterson noted that the AAAC (Astronomy and Astrophysics Advisory Committee) had considered the problem, and the single thing they could identify was that there were very good proposals, and just not enough money. Dr. Jernigan thought that the way to identify improvements to R&A would be to ask: if more resources were made available, how might one deploy those resources effectively? Dr. Jill Dahlburg agreed, as this also would take off the table what would be cut. Dr. Gaudi mentioned that his Early Career award from NSF, 5 years in length, went far in taking pressure off proposal writing; longer awards can really transform early career stages. Dr. Running suggested the use of pre-proposals, to ease the pressure of proposal writing. One Earth Science strategy had been to write narrower proposal calls on tighter topic areas. ESD did not show interest in pre-proposal mechanisms, but Dr. Running felt they could be valuable. He also supported the idea of longer awards. Dr. Peterson noted that the Astrophysics Division (APD) once supported 5-year awards, the intent of which was to award more to early-career researchers, but the division in fact ended up awarding 2/3 of the awards to late-career researchers, who had the experience to better envision a 5-year horizon. One downside is that longer awards do tie up funds in outyears and hinder support for rapidly developing areas; he still felt 3 years was optimal. Dr. Gaudi felt that NSF invests in people, not long-term visions, and that the freedom of the long-term award is that it allows the development of long-term visions. Dr. Dahlburg noted that high-risk/high payoff proposals were often hard to fund because reviewers are unfamiliar with more innovative areas, which illustrates the hindrance to advancing revolutionary ideas; ideas can't grow with excessively conservative reviewers who don't understand the concept they're reviewing. Dr. Desai agreed, and supported maintaining a separate pot of funds to support these disruptive ideas. Dr. Paul Hertz mentioned that the NIAC program produced the starshade concept, and it might be beneficial for NIAC to brief the SC. Dr. Bernstein said there are also cases where reviewers understand the idea, but still focus on implementation weaknesses, hence failing to award riskier concepts. Dr. Verbiscer felt it important to note that R&A also requires high-quality reviewers. If programs are too large, it's harder to bring in enough expertise (too many conflicts of interest).

Internal Scientist Funding Model

Dr. Newmark presented a briefing on a new Civil Servant Internal Scientist Funding model being adopted by NASA, with the goal of optimizing the NASA workforce's productivity and realizing its leadership potential, as well as helping these civil servants stay current in their fields. His intent was to show that there is no negative impact on the community via this model, which he felt was a win-win situation.

There are about 1000 civil servant scientists at NASA. Of the 1000 scientists, this activity is addressing about 150 full-time equivalents (FTEs) (spread over 350 scientists), who are funded through competed research awards. Eighty-five percent of the funding for civil servant scientists comes from flight projects, science teams, Center internal funding, directed supporting research, and technology. In response to a question, Dr. Newmark confirmed that NASA does have a standard review process that can lead to the firing of a civil servant. Dr. Flanagan noted that one way to pay NASA FTEs is to allow them to compete for an R&A project. Dr. Newmark agreed, and added that NASA has found that historically at SMD, the percentage of dollars that go to NASA civil servant scientists does not change. The point here is that there is no change in the balance that has been established over many years. Dr. Secada supported the thinking behind historical balances, which he thought to be suitably predictable. Dr. Newmark emphasized the key point, which is that the intent is not to quell competition. Rather, NASA is looking for ways pooling to

pool civil servants together on big, critical-mass topics. They can still compete for ROSES funds, but the expectation is that they will end up proposing to ROSES less frequently, because they are spending time on the some larger, directed questions. These proposals will still be subject to external review and evaluation, and will be directed at a collaborative project involving the civil servant scientists and their centers. Essentially, SMD will be taking money from the R&A pool and directing it toward these pooled civil servant scientists.

Dr. Gaudi felt the model sounds as if NASA is removing peer review. Dr. Desai asked how NASA will determine what can be done best at NASA centers for topics that are traditionally in the R&A program. Dr. Newmark answered that the intent is to look for problems that can best be done at NASA. Dr. Desai cited CCMC as a good example for the community, but not for R&A. Dr. Newmark emphasized that the model will be used to help NASA scientists to continue their forefront work. It is not meant for small one-person projects, it is meant to fund teams to work on bigger issues. The amount of directed R&A work at the Centers will be increased. All directed R&A work will be collaboratively planned between the Centers. Headquarters, and the SMD divisions, and will be peer-reviewed. The fraction of R&A funding going the Centers will remain consistent with historical levels, and NASA will be tracking the impact of the changes, heeding feedback mechanisms to ensure that the external community is not negatively affected.

Dr. Flanagan asked if the civil servant scientists were receptive to this idea. Dr. Newmark said that most are trying to understand the process, with the usual range of opinions. Currently, NASA is working out internal directed-work packages to address top-down strategic subjects. Dr. Dan Evans remarked that the effort was to identify the work that has been undertaken by the Center for a long time, and which has also undergone rigorous peer review. He was very cognizant that this model must be revenue-neutral. Dr. Peterson asked what fraction of the funding would go to contractors. Dr. Hertz replied that the model funds work, not people, and that NASA is committed to keeping the model revenue-neutral. The percentage of funding, over time, will not change. Dr. Hertz added that other Federal agency scientists do not have to compete for funds, unlike the case at NASA. Dr. Secada said he would like to hear about the sort of specific work that NASA is uniquely placed to do. That clarification would be compelling and would make the community much more sympathetic to the argument. Dr. Desai felt that the model might stifle the small, one-idea scientist in the community. Dr. Flanagan also militated for hearing a concrete idea. Dr. Evans offered two examples in Astrophysics: one is the development of an x-ray microcalorimeter for future strategic missions, and the other is the development of very large reflecting x-ray mirrors. Dr. Flanagan noted that GSFC does have a core microcalorimeter group, and felt there was some value in providing stable funding for such targeted groups.

Public Comment

Dan McCammon felt that NASA had not addressed the long-term effect of the internal funding model, as competition controls the kind of people it hires and funds. The model also seems to detract from a long-term focus on competing to get the best work done. Mark Bautz, of MIT, said he had been listening with interest, and thought the model was good in some respects, as some problems require a larger scale effort than is typically supported by R&A. Furthermore, NASA centers are not the only sites that would benefit from long-term R&A programs.

WFIRST Update

Drs. Dominic Benford and Jeffrey Kruk presented an update on the development of WFIRST. Dr. Kruk, Acting Project Scientist for WFIRST, introduced the details of the mission. WFIRST has been the top priority for large space missions in the last Astrophysics Decadal Survey, focusing on dark energy, the fate of the universe, the distribution of planets around the stars, and technology development for the exploration of new worlds. Of the five discovery areas in the Decadal Survey, WFIRST was found to be a widely capable mission that could address a large fraction of all of them. Its enabling aspect is a field of view (FOV) that is 100 times that of HST and JWST. WFIRST will produce high-resolution maps of the entire universe, with the same resolution of HST but to a higher redshift in near-infrared. It will also advance the field of coronagraphy. WFIRST will be the first NASA Astrophysics mission to bring us into the Big Data era, with its potential for large-scale data mining. The "speed" of WFIRST provided by its expanded FOV is unprecedented. It will be able to produce a deep field survey with the same time exposure as HST, and will bring 100 times the sample size. Rare galaxies will be discovered. WFIRST will also bring new insights into dark matter, the first galaxies and the early universe, a census of exoplanets, data on expansion of the universe, and it will directly image other worlds with a thousand-fold gain over current capabilities. WFIRST will be able to survey the HST universe in 10 weeks, at the same sensitivity and resolution. WFIRST is expected to discover 300-plus Earth-mass planets beyond 1 astronomical unit, through the technique of microlensing. The present design of the observatory has it placed at the Sun-Earth L2 point, where it will use K_a and S bands to carry large volumes of data. WFIRST will launch on a Delta Heavy or Falcon Heavy launch vehicle.

Dr. Benford, Program Scientist for WFIRST, addressed instrumentation, primarily the Wide Field Instrument, and the coronagraph for starlight suppression. Some milestones coming up include a Systems Readiness Review and Mission Design Review in July of this year, working toward launch in 2025. Programmatic issues have been identified. A mid-term assessment yielded a number of comments; one of which called for a cost estimate, which will take place this summer. In addition to a grass-roots cost assessment, the mission will also bring on independent NASA cost estimates, as well as external (Aerospace) estimates, and those from the WFIRST Standing Review Board. The assessment also called for descope in the event of cost growth that imbalances the Astrophysics program portfolio, though with the intent of retaining science value. WFIRST total mission cost is estimated to be $3.2B in real-year dollars ($2.4B in FY10 dollars). The mission will have a comprehensive descope list associated with various cost and science impacts. The assessment also included a comment on the coronagraph ($350M), which is not required for mission success. The coronagraph is a class C instrument in terms of risk (e.g., on par with an Explorer mission). WFIRST will be studied as a starshade-compatible mission, in case the next Decadal Survey calls for it. A starshade would be complementary to the coronagraph to provide even better starlight suppression. WFIRST's technology development was begun in February 2014 and successfully completed in January 2017. The mission has now addressed all the top technical risks. There were 5 milestones for the infrared detectors (Teledyne H4RG arrays), which are now at technology readiness level (TRL) 6, and well ahead of the requirements. The mission is getting ready to make procurement for the actual flight detectors (range of 1 to 2 microns, good down to 0.5 micron). The coronagraph must work down to 450nm. The Wide Field Instrument has 8 filters, and the coronagraph has 17 (including engineering filters). Detectors have been characterized; dark current is unchanged with

radiation testing, and persistence reliably exceeds requirements. The coronagraph technology status is at TRL 5. WFIRST will use an inherited telescope, which has come with a complete survey of 11,000 artifacts, all of which have been assessed. The risks of utilizing the hardware are now largely mitigated. A report is available at https://wfirst.gsfc.nasa.gov/newsroom.html.

Dr. Robinson asked what the biggest worry was for risk to schedule or budget. Dr. Kruk felt that scaling up the analysis for the grism tool was one concern, but other than that, he had few technical worries. He thought that there is certainly much to do, but all in the category of normal work. Dr. Flanagan asked about the biggest budget worry. Dr. Benford felt this to be overall cost, and that care would have to be taken about executing any de-scopes. However, there is a PBR to work against, and the team is also working a mission concept that fits the 5-year run out numbers. Dr. Kruk added that WFIRST was adding filters that are going into the optical part of the spectrum, and that a blue filter is new. There had been lengthy debates that led to increasing the number of filters for improved science value.

Discussion, Findings and Recommendations

The Committee reviewed the BDTF finding on HEC, and accepted it by acclamation, given that the HEC effort was already funded.

BDTF Finding:

In 2016, the NASA HEC facilities grew to support an additional 42% in compute capacity as measured in standard billing units. Additionally, the application support team is proving to be effective at significantly improving the efficiency of codes running on the HEC assets. The HEC management team is proactively attempting to address platform oversubscription concerns via collaborative efforts with NASA mission teams, independent of budget requests for additional platform resources. The Task Force enthusiastically endorses these efforts to improve both NASA's HEC capacity and the efficient utilization of the HEC resources.

Dr. Holmes said he would find it useful if the SC could look at the Task Force's four study topics and list of recommendations to see if BDTF was on the right track.

Dr. Running reviewed the 9 ESS findings, most of which required no actions from SC. The 9th finding on socioeconomic implications of improved Earth observations from space was considered as a SC finding. Dr. Running noted that a big issue is how far to track these effects, but he felt it worthwhile for the SC to comment on the finding as a general concept, with a cautionary statement on the appropriate amount of time to devote to this. This would be a new type of analysis for NASA to consider.

ESS Finding:

ESS supports efforts to better assess socio-economic implications of improved Earth observations from space. Related to this topic, ESS supports efforts to improve integration between Applied Sciences and Research, and the creation of the consortium to assess socio-economic values of improved Earth observations from space.

The Committee reviewed the ESS recommendations, all of which were deemed as direct messages to the

division director. Regarding the GPRAMA recommendation, Dr. Peterson felt it prudent to first see how ESD fares from the recommendation, before it might be adopted by other divisions. Drs. Secada and Dahlburg felt that clarification of the GPRAMA reports in general could be helpful in writing to the proper audience and communicating the significance of NASA work. Dr. Peterson suggested that ESD use good examples from APD and HPD as a start. Dr. Secada felt that the recommendation was wishy-washy compared to Dr. Running's strong comments about the text component, and that a stronger statement would be more likely to engender a change.

Dr. Peterson addressed the Internal Science Funding model. While feeling the skepticism of the SC, he felt the Committee had become less skeptical when presented with more specific examples—these were all in technology and seemed quite reasonable. Dr. Gaudi asked for more details, and still thought the model would suppress competition. Dr. Peterson noted that NASA had adopted a similar model 20 years before and had decided it was redundant. He agreed, however, that the model could be useful in some niche areas. Dr. Flanagan remarked on maintaining the usual tension between security and complacency. Dr. Desai felt that cherry-picking technology could result in throwing good money after bad, or going for the easy job. Dr. Secada thought that the R&A restructure comments contained a potential positive in releasing key players from writing proposals, which could serve as a pilot for leveling the playing field for some unique talents.

Outbrief for SMD Associate Administrator

SC briefed the SMD AA on the meeting's proceedings, and Dr. Running presented the ESS socioeconomic finding that was based on the work of Wielicki, *et al.* Dr. Zurbuchen was familiar with the work and received it with affirmation. He similarly accepted the BDTF finding on HEC. Dr. Peterson addressed the R&A charge, and asked for further clarification. Dr. Zurbuchen said he thought it was an important program, a strategic element of SMD, and that it was just time to look at it holistically, as it has not been assessed in a while. He asked the SC to concentrate on the three questions he had presented earlier. Dr. Desai asked whether a NIAC-type initiative might be adopted by SMD. Dr. Zurbuchen noted that this would be an important discussion that needs input from the team: Should SMD R&A focus on the "what" or the "how"? Is there a strong signal that not supporting high-impact research? Should it invest 3 percent of the R&A program on high-risk/high payoff proposals? He asked the SC to determine whether or not there was a real problem, and if so, find an implementation and then review it. Dr. Zurbuchen requested both a data assessment and a perception assessment, or a type of community survey. He preferred not to take the issue to NAS and wait 18 months. His personal feeling was that this is an operationally-focused matter. For example, the SC may find that there is an implicit bias in the review process. Dr. Zurbuchen suggested that one way might be for SC to arrive at a recommendation for SMD to look at, then secondarily consult the other committees via survey or other means. It will be useful to see how the interaction goes, and exercise the new machine. He urged the SC to leave off the hardware piece, and concentrate more on the intellectual ambition. Is there a bias here for or against risk?

Dr. Peterson raised general SC concerns about the internal scientist funding model, and how it might be implemented. Dr. Zurbuchen reminded members that the model is the result of an Agency directive, but that a finding asking for more clarification would be appropriate. The decision is made, and the question is how it can be made to work best for NASA's scientists and the community at large. There is 3-year

review cycle associated with the model, so NASA can get off the train if it is going in the wrong direction. It is mostly noise at the moment. There will be quantitative data going forward. Dr. Desai expressed unease about the possibility that the community will have zero input into what gets selected. Dr. Zurbuchen noted that all the packages will definitely go through peer review, and these reviews will force a discussion if there is a problem. Dr. Gaudi said he would be interested to see how the model affects intra-center politics, which could be a serious issue. Dr. Zurbuchen thought this was a good question, and spent a lot of time building in responses to this, to make sure ratios do not get out of whack. SMD has done its due diligence, and will just have to see if it works. Dr. Flanagan noted that the perception of the Astrophysics community is that there will be an impact on competition. Dr. Zurbuchen said that NASA has adopted an approach, and will have to wait to be able to provide actuals. Some variables will be kept constant, but NASA wants to divest research that is no longer relevant; discoveries are hard to plan. The way he thought about it was as a chair of a review committee, and he added that the new model is not equivalent to the one NASA had 20 years ago.

Dr. Robinson raised a concern about language in the New Frontiers AO that requires 75 percent of a returned sample be confiscated for future use. He felt this requirement was excessive, especially if the sample is small. The requirement could have the unintended consequence of increasing spacecraft/launch vehicle costs, secondary to increasing mass requirements. Dr. Zurbuchen thanked him for the comment, and felt it was a good point. Dr. Flanagan wanted to acknowledge how much the science community esteems and trusts its NASA civil servant colleagues, whom they regard as a national treasure. Dr. Zurbuchen agreed wholeheartedly and felt this acknowledgement could constitute a good finding. He cited Dolores Holland, a mentor to John Grunsfeld, as one of the many people who make NASA great. He requested feedback about his morning briefing. Dr. Robinson asked to have programs identified with each mission/project. Dr. Dahlburg judged Dr. Zurbuchen's briefing to have been spectacular, and added she had greatly appreciated a past Grunsfeld talk that had featured magazine covers of the future (highlighting NASA technologies), which she had since appropriated as a tool for her own talks. Dr. Robinson lastly observed that he had witnessed periodic assessments at centers, which tended to result in reduced pay for contractors and thus impair morale.

Dr. Peterson adjourned the meeting at approximately 1:00pm.

Appendix A
Attendees

NAC Science Committee Members
Bradley Peterson, Ohio State University, ***Chair, Science Committee***
Susan Avery, Woods Hole Oceanographic Institution *(via telecon)*
Jill Dahlburg, Naval Research Laboratory, Chair, Heliophysics Subcommittee
Mihir Desai, Southwest Research Institute
Douglas Duncan, University of Colorado Boulder
Kathryn Flanagan, Space Telescope Science Institute
B. Scott Gaudi, Ohio State University, Chair, Astrophysics Subcommittee
Tamara Jernigan, Lawrence Livermore National Laboratory
Carlé Pieters, Brown University
Mark Robinson, Arizona State University
Steve Running, University of Montana, Chair, Earth Science Subcommittee
Walter Secada, University of Miami
Anne Verbiscer, University of Virginia
Elaine Denning, NASA Headquarters, ***Executive Secretary, Science Committee***

NASA Attendees
DaMara Belson, NASA
Dominic Benford, NASA HQ
Max Bernstein, NASA HQ
Dan Evans, NASA HQ
T. Jens Feeley, NASA HQ
Michael Freilich, NASA HQ
Hashima Hasan, NASA HQ
Jeffrey Hayes, NASA HQ
Paul Hertz, NASA HQ
Jennifer Kearns, NASA HQ
Jeff Kruk, NASA GSFC
Peter Meister, NASA HQ
Jeff Newmark, NASA HQ
Marian Norris, NASA HQ
Mike O'Hara, NASA HQ
Kirsten Petree, NASA HQ
Arik Posner, NASA HQ
Sandra Smalley, NASA HQ
Lucia Tsaoussi, NASA HQ
Pete Vrotsos, NASA HQ/HEO
Dan Woods, NASA HQ
Thomas Zurbuchen, SMD AA, NASA HQ

Non-NASA Attendees
Ellis Baggs
Emil Baggs

Francesco Bordi, Aerospace
Anne Connor, Harris Corp.
Heather Futrell, Booz-Allen
Grace Hu, OMB
Nikole Lewis, STScI
Ana Wilson, Ingenicomm, Inc.
Joan Zimmermann, Ingenicomm, Inc.

Telecon/Webex Attendees
Barbara Adde, NASA
Mitch Ambrose, AIP
Amanda Arnold, Arizona State University
Louis Barbier, NASA
Mark Bautz, MIT
Linda Billings, NIA
Heather Bloemhard, AAS
Michelle Calloway, NASA
Jonathan Charleton, U.S. House of Representatives
Dianne Cheek, NASA
Stephen Clark, Space Flight Now
James Dean, Florida Today
David Eisenman, NASA JPL
Jeff Foust, Space News
David Gump, Deep Space Industries
Wade Heck, BWX Technologies
Charles Holmes, Chair, NAC SC Ad Hoc Big Data Task Force
Lane Innis, Aero Science
Ben Kallen, Lewis-Burke
Jennifer Kearns, NASA SMD
David Ladler
Jared Leisner, NASA
Amanda Leitz, Ball Aerospace
Sarah Lipscy, Ball Aerospace
James Lochner, USRA
Linda Karanian, Karanian Consulting
Dan McCammon, University of WI
Alfred McEwen, Arizona University
Duane McMahon, NASA
Michael Meyer, NASA
Kelly Miller, SWRI
Peter Plavchan, Missouri State University
Marc Postman, STScI
Kurt Retherford, SWRI
Blaine Rivas, U.S. House of Representatives
Christy L Rivera, NASA
Andrew Rowe, NASA
Nick Saab, Lewis-Burke
Stephanie Sanzone, GSA
Marcia Smith, Space Policy Online
Louis Stark, ESA

Kim Terrell
Peter Townsend, Ball Aerospace
Dan Williams, Busek Co.

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. Mihir Desai
Southwest Research Institute

Dr. Douglas Duncan
University of Colorado at Boulder

Dr. Kathryn Flanagan
Space Telescope Science Institute

Dr. Bernard Scott Gaudi
The Ohio State University

Dr. Tamara Jernigan
Lawrence Livermore National Laboratory

Dr. Carlé Pieters
Brown University

Dr. Mark S. Robinson
Arizona State University

Dr. Steve Running
University of Montana

Dr. Walter G. Secada
University of Miami

J. Marshall Shepherd
University of Georgia

Anne Verbiscer
University of Virginia

Ms. Elaine Denning
Executive Secretary
NASA Headquarters

Appendix C
Presentations

1. Science Mission Directorate Report; *Thomas Zurbuchen*
2. TRAPPIST-1 Exoplanets; *Nikole Lewis*
3. Earth Science Subcommittee Report; *Steve Running*
4. "Ceres: Remarkable Dwarf between the Inner and Outer Solar System;" *Carle Pieters*
5. Joint Agency Satellite Division; *Sandra Smalley*
6. Update: FACA Committee Charters; *Elaine Denning, Jeff Newmark*
7. Deep Space Network/SCaN Update; *Peter Vrotsos*
8. Ad Hoc Big Data Task Force Report; *Charles Holmes*
9. Science Committee Retool; *Bradley Peterson, Elaine Denning*
10. Research and Analysis Improvement; *Max Bernstein*
11. Internal Scientist Funding Model; *Jeff Newmark*
12. WFIRST Update; *Dominic Benford, Jeffrey Kruk*

Appendix D
Agenda

NASA Advisory Council
Science Committee

April 12-13, 2017

NASA Headquarters
Room 5H41

Agenda
(Eastern Time)

Wednesday, April 12

9:30 – 9:45	Opening Remarks / Introduction of Members	Ms. Elaine Denning Dr. Bradley Peterson
9:45 – 10:45	Discussion with SMD AA	Dr. Thomas Zurbuchen
10:45 – 11:00	***BREAK***	
11:00 – 11:40	TRAPPIST-1 Exoplanets	Dr. Nikole Lewis Space Telescope Science Institute
11:40 – 12:00	Earth Science Subcommittee Report	Dr. Steve Running University of Montana
12:00 – 12:15	Discussion	
12:15– 1:15	***LUNCH*** – Member Research Presentation "Ceres: Remarkable Dwarf between the Inner and Outer Solar System"	Dr. Carle Pieters Brown University
1:15 – 2:00	Joint Agency Satellite Division	Ms. Sandra Smalley
2:00 – 2:30	Update: FACA Committee Charters	Dr. Jeffrey Newmark Ms. Elaine Denning
2:30 – 2:50	Other Updates from Committee Chairs	

2:50 – 3:00	Public Comment	
3:00 – 3:15	***BREAK***	
3:15 – 3:45	Deep Space Network Update	Mr. Pete Vrotsos
3:45 – 4:30	Big Data Task Force	Dr. Charles Holmes NASA (ret.)
4:15 – 5:00	Discussion	

Thursday, April 13

8:30	Re-open Meeting	Ms. Elaine Denning Dr. Bradley Peterson
8:30 – 9:15	Science Committee Retool Discussion	Dr. Bradley Peterson Ms. Elaine Denning
9:15 – 10:00	Research & Analysis Improvement	Dr. Max Bernstein
10:00 – 10:30	Internal Scientist Funding Model	Dr. Jeffrey Newmark
10:30 – 10:40	***BREAK***	
10:40 – 10:45	Public Comment	
10:45 – 11:15	WFIRST Update	Dr. Dominic Benford Dr. Jeffrey Kruk
11:15 – 12:00	Discussion, Findings and Recommendations	
12:00 – 1:00	Outbrief for SMD AA	
1:00	***ADJOURN***	

Dial-In and WebEx Information

For entire meeting April 12-13, 2017

Dial-In (audio): Dial the USA toll-free conference call number 1-888-592-9603 or toll number 1-312-470-7407 and then enter the numeric participant passcode: 5588797. You must use a touch-tone phone to participate in this meeting.

WebEx (view presentations online): The web link is https://nasa.webex.com, the meeting number is 991 353 215, and the password is SC@Apr2017 (case sensitive).

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