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MEETING REPORT

David J. McComas, Chair

Elaine Denning, Executive Secretary

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July 29, 2013

Welcome and Introduction

Science Committee Executive Secretary Ms. Elaine Denning called the meeting to order and made administrative announcements.

Dr. David J. McComas, Chair for the NASA Advisory Council (NAC) Science Committee (SC) opened the meeting and welcomed members. Dr. McComas welcomed new members Dr. Scott Gaudi, incoming chair of the Astrophysics Subcommittee (APS), Dr. Robert Lindberg, incoming Chair of the Planetary Protection Subcommittee (PPS), and Dr. Harry McSween, sitting in for Planetary Science Subcommittee (PSS) Chair Dr. Janet Luhmann. Dr. David Spergel, *ex officio* member, was also in attendance. New SC member Dr. Robert Kirshner joined the committee on the third day.

Dr. McComas noted that his term as Chair was coming to its end and that he would be cycling off of the Committee. He urged the Science Committee to continue to function as an independent advisory group that was not afraid to raise sometimes uncomfortable issues. He noted that, while not always popular, the discussion of difficult problems is critical to the Agency and truly appreciated by Administrator Bolden. Dr. McComas also reminded the Committee that under his Chairmanship, all formal Findings and Recommendations had been by complete consensus of the members who participated in the meeting where each issue was discussed (as opposed to voting or some other non-consensus process) and hoped that the Committee would continue this consensus practice for all future Findings and Recommendations.

MESSENGER End of Mission

Dr. Larry Nittler presented science highlights and an end-of-mission report for the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft at Mercury. Mercury is difficult to study; the only prior visit to the planet was by Mariner 10, in 1974-75, which entailed only 3 flybys. MESSENGER is the first spacecraft to orbit Mercury. Mercury is the smallest, densest planet, a planet of extremes, with the highest diurnal variation in temperature and a large iron core. It is the only other terrestrial planet besides Earth that has an internally generated magnetic field. There is a low abundance of oxidized iron at the surface, and previously reported, ground-based evidence for water ice. Compared to known exoplanets, Mercury is not unusual, in that it orbits closely to its star. Other dense exoplanets are inferred to be Mercury-like, thus illustrating Mercury's value in comparative planetology. Selected in 1999, the mission launched in 2004 and went into orbit in 2011. Six gravity assists were required. Ninety percent of the surface was imaged during 2008-9. The highly elliptical polar orbit ranges from 200-500 km at periapsis to 15,200 km at apoapsis. The mission has completed 4035 orbits, collecting data to answer science questions regarding planetary formation processes, geologic history, material structure, magnetic fields, and volatile element distribution. MESSENGER has accomplished all project level requirements at this point. The payload includes X-ray and gamma ray spectrometers, wide- and narrow-angle cameras, a laser altimeter, magnetometer, and an ultraviolet-to-near-infrared spectrometer.

The mission has produced more than 350 papers and several Science special issues. Final negotiations are in progress to produce a book over the next year. By February 2013, 100% coverage of imagery was

achieved, enabling the creation of a complete global multispectral map, with better than 1-km per-pixel resolution overall. Mercury's surface has been found to be sulfur- and volatile-rich, and iron-poor. The composition rules out many previous formation models, and indicates that starting materials were highly chemically reduced (high sulfur). Mercury possesses a very heterogeneous surface for a small planet, which points to an interesting geology that includes widespread volcanism, large expanses of volcanic plains in the northern hemisphere, and indications of a violent early start. A new landform, "hollows," has been seen; these are bright deposits inside rimless depressions, some with halos, within craters, thought to represent volatile loss. Lobate scarps, or large cliffs, are due to the contraction of the planet as it cooled. There is much more contraction than previously believed. Geophysical data has produced an inferred gravity map that postulates a solid inner core, liquid middle core, and solid iron-sulfur core layer, mantle, and crust. The magnetic field is dipolar, with the dipole displaced by about 500 km. The planet has a complex magnetosphere that interacts with the solar magnetic field and traps particles. The most abundant particles trapped in the magnetosphere are energetic electrons. Mercury has a weak exosphere, too weak to be called an atmosphere. Calcium has an unusual peak at the dawn terminator, which might be related to micrometeorite impact. At the poles there are radar-bright deposits (as seen from Arecibo in 1992) in craters. Thermal modeling now indicates ice/organic stability where these deposits are located. Neutron emissions are sensitive to hydrogen; they decrease at the north pole, which supports the water ice theory. Deep MESSENGER imaging of deposits also reveals brightness variations in deposits. A low altitude campaign, below 200 km since April 2014, and at 20-100 km since August 2014, has allowed unprecedented resolution of surface features, revealing extremely young hollows, dark material at the Scarlatti crater, and very few impact craters in the hollows. A volcanic vent near Copland crater was explored by high-resolution imagery, which demonstrated fluting and gullies from landslides. The low altitude campaign also allowed chemical measurements with a few-km resolution, with particular interest in magnesium/silicon compositional changes. There appears to be remnant crustal magnetism (magnetic materials in crust- thermal preservation over 4 billion years). Gravity anomalies are also seen in higher resolution passes. MESSENGER is now in its "XM2 Prime" mission, having eked out a bit more time. This extraordinarily successful mission is expected to end around April 30, when the spacecraft impacts the planet.

Dr. McSween asked if there were any theories about the large iron core. Did a giant impact hit Mercury and knock off much of the mantle? Dr. Nittler noted that earlier models of the planet had predicted severe loss of volatiles; however significant amounts of chlorine on the surface may argue against a giant impact. Separation of metals and silicates occurred early in Solar System history. Dr. Carlé Pieters asked if the plasma environment combined with unusually displaced magnetic poles suggested anything about the deposits at the poles. Dr. Nittler replied that this was unknown. There is a known landing spot for BepiColombo MESSENGER on the far side of planet, with a fairly long landing ellipse. The crater is predicted to be 10s of meters in diameter. Dr. McComas suggested MESSENGER hold a Lessons Learned briefing in the future. Asked what was next for Mercury, Dr. Nittler anticipated that BepiColombo provide better coverage of the southern hemisphere, as well as more data about the curious dipole displacement. It would be great to have a lander at the pole, or sample return. Dr. McSween asked if it were dynamically possible to have meteorites from Mercury on Earth. Dr. Nittler indicated that probably one out of tens of thousands of stony meteorites could be from Mercury.

Planetary Protection Subcommittee Report

Dr. Robert Lindberg, Chair of the Planetary Protection Subcommittee (PPS), presented a status of the PPS, bringing forward a recommendation that had been previously tabled, concerning compliance with planetary protection (PP) concerns and the PP letter. The issue had come up in the context of Mars Science Laboratory (Curiosity rover) surface operations and proximity to "special regions" that might possibly support or harbor microbial life. The Mars Science Laboratory (MSL) science team needs to be cognizant of these regions and must report to the Planetary Protection Officer (PPO) when such regions are approached. PPS had previously considered addressing a letter directly to the Science Mission Directorate (SMD), but has held off on this move as things were moving in the right direction, and instead has followed up on improving the communication process. The MSL science team recently gave the PPO advance notice of a paper that addressed a relevant scientific finding, but PPS feels it would have been better to have been told at the time of the actual finding. PSS is looking to continuing improvement of communications so the PPO can weigh in on planned Mars surface operations to avoid special regions...

A second finding concerns collaboration with the Europeans, particularly in holding a joint meeting with the Planetary Protection Working Group (PPWG) of the European Space Agency (ESA). PPS is still working on getting resources from NASA to carry out this meeting. Joint meetings will be increasingly important to future sample return, human exploration, non-state actor missions, and PP considerations in much greater detail. Dr. McComas noted that he did raise the latter (non-state actor) issue with the NAC, and reported having had a good introductory discussion. Dr. Spergel added that the National Research Council is addressing PP concerns via a joint study between NRC and the Europeans, focused on an evaluation of PP rules and the Committee for Space Research (COSPAR) process, which is still in work.

Dr. Catharine Conley, NASA PPO, added that there is a proposal from the European Science Foundation on PP for the Mars 2020 rover. There is also a possibility of the Space Studies Board (SSB) doing an independent activity. SSB also organizing a study on PP for sample return.

FY16 NASA SMD Budget Overview

Mr. Craig Tupper presented the latest budget for SMD. Most of the news is good, as the budget runout is up a little. The budget covers operations for 97 missions, 124 spacecraft, and a stable suborbital program, for all the divisions interconnected in science themes. The budget strategy includes an increasing cadence of some principal investigator (PI)-led flight missions, particularly in the Earth Science Division (ESD) Venture Class category, and the Planetary Science Division (PSD) programs of New Frontiers and Discovery.

The budget includes funding for a sustained land imaging capability beyond Landsat 8, the Mars 2020 rover, and some funding in the out years for a Europa mission, as well as an increase in funding for the detection and characterization of near-Earth objects (NEOs). A New Frontiers Announcement of Opportunity (AO) will be supported in Fiscal Year (FY)16. The Stratospheric Observatory for Infrared Astronomy (SOFIA) is back in the budget, and will undergo a Senior Review process in 2016. The Wide-Field Infrared Survey Telescope (WFIRST) mission in the Astrophysics Division (APD) is still in pre-formulation, with Phase A funding in 2017. There will also be an increase in collaboration with the Space Technology Mission Directorate (STMD) and a new Cooperative Agreement Notice (CAN) to support

Science Technology Engineering and Mathematics (STEM) education.

The top line budget for FY16 and out is up about 5%, with a 1% to 1.5 % increase per outyear. All the themes are stable: the James Webb Space Telescope is at $645.4B for 2015. PSD contains projected growth in Discovery to possibly support a launch every two years. Outer Planets (OP) is funded at $181M in FY15, which includes Europa studies. There will be an Explorer AO in the Heliophysics Division (HPD) no earlier than FY16. An OP decrease in 2018 reflects termination of the Cassini mission.

In general, cost and schedule performance continues to be successful in coming in at, or under, budget. The total cost to develop 14 science missions launched in the last 3.5 years exceeds the sum of original estimates by only 9%. Excluding MSL, the budgets have been coming in at a slight underrun of -1%. Future mission opportunities include an Europa instrument investigation, and a SOFIA instrument AO will be coming out this week.

Asked how SMD would distribute unallocated funds in the case of a more favorable appropriation, Mr. Tupper indicated that Congress is fairly specific about where the money goes. This direction does not have the force of law, but is detailed in committee report language. NASA treats the language very seriously. Sometimes NASA can propose a change to the number if there is a strong argument. Dr. McComas asked for more details about an STMD collaboration. Dr. Marc Allen noted that the Office of the Chief Technologist keeps this communication going, working closely with STMD in its 9 program areas, such as coronagraph development and small spacecraft technology. STMD is looking for opportunities in the Human Exploration and Operations Mission Directorate (HEOMD) to fly miniaturized instruments, for example. SMD is trying to leverage their program (their budget) for various planetary missions. Dr. Spence asked when Europa mission would become a real mission. Dr. Allen replied that this would occur when it reaches technical milestones; there is a budget wedge for Europa in the outyears to continue development. The mission might reach Key Decision Point-A (KDP-A) this year, perhaps. SMD is not in complete control of that schedule. Dr. Mark Robinson asked how much NASA would be able to shape the final budget. Mr. Tupper explained that the Office of Management and Budget (OMB) provides budget guidance over a 5-month period of negotiation with the Agency. SMD then talks to its field centers, etc. during this period, forming the basis of the budget request. Dr. McSween asked about funding for STEM education. Mr. Tupper projected the SMD STEM budget to be roughly $42M, plus another $30M spread across flight missions. After NASA completes the Education CAN, it will be in a better position to understand the ramifications. The outcome may not be available for the 2017 budget request planning period. Congress did in fact increase spending for Education. Dr. Spence asked whether a single thing turned the tide on performance, and whether are there areas of concern. Mr. Tupper ascribed better performance to the use of independent cost estimates, and holding missions to 70% cost and schedule estimating, and adding rigor to the technical process of going through KDPs. For the future, NASA is hopeful that there will be some underruns, and there are no big concerns at the moment. JWST is going very well, and the Agency is optimistic that it will fly in October 2018. Mr. Tupper noted that criticism had been leveled at Headquarters in the past for jerking budgets around to fix problems. Budget stability in the last 4 years or so has allowed for better performance numbers.

Earth Science FY16 Budget and Division Update/Earth Science Subcommittee

Dr. Michael Freilich, Director of the Earth Science Division (ESD) presented the ESD budget for FY16, which is much improved at a $1.7/1.8B per year level. Budget requests and appropriations have been relatively stable. In the FY16 request, the Administration has asked for a measurable increase in the ESD budget, which comes with increased scope. The budget is up about $130/140M per year over the outyears, reflecting the ESD mandate for long-term data sets that were previously covered by other agencies (primarily the National Oceanic and Atmospheric Administration (NOAA)). ESD is now responsible for precision ocean altimetry from space, solar irradiance, ozone profile, and the Earth radiation budget, starting in FY16, as well as a Sustainable Land Imaging Program, along with the U.S. Geographical Survey (NASA funds flight hardware). The first tier of this effort will be the launch of a thermal infrared imager (TIR-FFD) in 2019 to continue measurements in the thermal infrared. Landsat 8 launched in 2013, but its infrared (IR) instrument is slightly degraded, thus TIR-FFD was designed to address this problem in the short term. The second tier is an upgraded Landsat-9 (launch in 2023), which will leverage design and spare parts from Landsat 8. The design will also be extended to a five-year lifetime for the spacecraft, improved from three years. Focused technology development will inform the designs of Landsat 10+. This is a multi-mission, multi-decadal plan. A five-year design life translates to about 11 years of lifetime, thus the risk of having gaps between launches is relatively low. Improvements in spectral and spatial resolution and coverage will also be an integral part of the technology development process.

The budget will also support continued development and launch of the Stratospheric Aerosol and Gas Experiment-III (SAGE III), ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS), and Global Ecosystem Dynamics Investigation (GEDI) to the International Space Station (ISS), as well as the Cyclone Global Navigation Satellite System (CYGNSS), Tropospheric Emissions: Monitoring of Pollution (TEMPO), Gravity Recovery and Climate Experiment Follow On (GRACE-FO), ICESat-2, Surface Water Ocean Topography (SWOT), NASA-ISRO Synthetic Aperture Radar (NI-SAR), and Pre-Aerosol, Clouds, and ocean Ecosystem (PACE). The Venture Class program is on schedule with full funding. The Orbiting Carbon Observatory-3 (OCO-3) is scheduled for late 2017. Climate Absolute Radiance and Refractivity Observatory (CLARREO) technology demonstration instruments will be flown to ISS in late 2019.

The key to the ESD is to understand Earth as an integrated system, containing many different variables with interactions between physics, chemistry, biology, and radiation. The 2015 ESD Senior Review will evaluate numerous missions including Terra, Gravity Recovery and Climate Experiment (GRACE), Aqua, and Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO). The Tropical Rainfall Measuring Mission (TRMM) spacecraft will be turned off on April 8; it has run out of fuel and its function is being replaced by the Global Precipitation Measurement (GPM) satellite. The Quick Scatterometer (QuickSCAT) satellite will be replaced by RapidSCAT, to be launched in September 2015. QuickSCAT had opted not to send a proposal to the Senior Review, which considers the value of continuing time series missions, as well as their usefulness to other agencies and user communities for operational importance. For this reason, a National Interests panel is also used in the Senior Review process for ESD. Dr. Pieters asked if continuity was defined by lifetime, or expected extension. Dr. Freilich replied that the system design has to balance risk of continuity against the scope of the portfolio. If there is a vulnerable measurement, it can be mitigated by looking more closely at operations.

Over 11 months, ESD has launched five missions or major instruments: GPM, OCO-2, RapidSCAT, Cloud Aerosol Transport System (CATS), and Soil Moisture Active-Passive (SMAP) (the latest in January 2015). Another 11 missions are scheduled between now and 2022. SMAP's first light image was released in late February. It is now in science mode and currently completing one orbit cycle's worth of data. OCO-2 has released standard products that include global measurements of CO_2 concentrations. GPM observed Super Typhoon Hagupit on December 5, 2014 over the Philippines, and is being used to improve the track prediction of future storms. GPM, within its first year of science operations, has produced all of its planned standard data products, including constellation-merged products. The database, called IMERG (Integrated Multi-satellitE Retrievals for GPM), contains data from multiple missions measuring precipitation, ice mass, sea level, soil moisture, sea surface salinity, and subsurface water — the entire hydrologic cycle.

CATS (Cloud Aerosol Transport System), an ISS instrument, launched in 2015 and is now making precision measurements of vertical profiles of aerosols and clouds. ESD is using ISS a fair amount. Asked if there were a risk of running out of real estate on ISS, Dr. Freilich noted that most instruments can be serviced or retrieved. ISS is not close to running out of space.

Venture class missions in ESD are comprised of suborbital, smallsat, and instrument strands, and are well into the second round of solicitations, on time and with a full budget. Thus far the division has flown off five, 5-year suborbital missions that were chosen in 2010. The first smallsat was the CYGNSS constellation of L-band receivers to observe developing storms and hurricanes. A second selection has been made, and the intent is to have an Earth Venture class instrument (EV-I) solicitation every 18 months.

Research, Applied Sciences, Technology, and Flight are the four ESD categories. The division has maintained the balance in the program as the budget has increased since 2009: 38% is devoted to non-flight activities, and 62% to flight. The Technology office was given a small increase for cubesats.

Dr. Spergel asked whether ESD had increased its cooperation with STMD. Dr. Freilich noted that the cooperation occurs at different Technology Readiness Levels (TRLs); STMD looks at much earlier TRLs in general, with cross-directorate impacts. ESD is also working with other divisions on cubesat flight validations. A statement of task for a new ES Decadal Survey (DS) is complete and should be released in 2017. Dr. McComas asked if any new responsibilities had been transferred to ESD from NOAA. Dr. Freilich replied that the Administration recognizes that NOAA needs to focus on its weather prediction/life and property short term/near term forecasting. This eliminates the year to year jockeying. NASA is concentrating on longer term issues. Dr. Freilich felt that the division of labor was appropriate and working well.

Earth Science Subcommittee

Dr. Steve Running related that ESS has not met since the last Science Committee meeting and therefore has no report.

Discussion

The Committee briefly discussed potential findings. Dr. Spence addressed a question to Dr. Freilich on the next Decadal Survey and how it influences current the budget. Dr. Freilich cited more complications for Earth Science as it involves other agencies such as NOAA and the U.S. Geological Survey (USGS). However, he felt that a realistic and executable, balanced program was in place. Dr. Spergel noted that a report on lessons learned, led by Alan Dressler, is in under way. This will include a long discussion of the Earth Science Decadal Survey in terms of whether it addresses the broader program. The statement of task ultimately addressed the broader program, including applications.

The Committee discussed the NASA non-concurrence with its previous travel recommendation. Dr. McComas felt the Committee should respond to the non-concurrence language. Dr. Spergel noted that the NRC Science and Technology Council reviewed the travel policies of agencies with budgets of over $12B, and that OMB is handing new rules to the agencies as a consequence. New instructions were given to the agencies in January, constituting an opportunity for NASA to make some changes. Dr. Spergel felt that the NASA non-concurrence contains contradiction to what is known. The Committee requested a briefing from the Office of the Chief Financial Officer (OCFO), author of the current travel policy language. Dr. Robinson observed that lack of clarity in the current language may be causing an overly conservative response.

Tuesday, April 7, 2015

Ms. Denning made some morning announcements, including an agenda change to include a requested OCFO briefing on travel during the morning session.

JASD Update

Dr. Steve Clarke, Director of the Joint Agency Satellite Division (JASD), reported on the activities of the division, which manages reimbursable programs, primarily for NOAA. JASD was established in 2010 at the demise of the National Polar-orbiting Operational Environmental Satellite System (NPOESS) and was set up to manage the Joint Polar Satellite System (JPSS), initially, primarily at the Goddard Space Flight Center (GSFC). JASD's function is to represent programs and projects at the Agency level, and represent reimbursable customers at the HEOMD Flight Planning Board. Dr. Clarke is a direct report to SMD Associate Administrator (AA) Dr. John Grunsfeld, and oversees four Program Executives and embeds from various offices at Headquarters. Recent activities include the launch of the Deep Space Climate Observatory (DSCOVR) in February from the Cape. Jason-3 now has a range date at Vandenberg Air Force Base for July 22. The Geostationary Operational Environmental Satellite- R Series (GOES-R) is scheduled for mid-March of 2016. TSIS-ISS, a solar irradiance sensor, will be flying in August 2017.

DSCOVR was launched by SpaceX and is in the process of calibrating and activating instruments. The spacecraft will reach L1 around June 7-8, when final calibrations will be made. Thus far the mission is going well, after resolving minor issues with the Faraday cup. Bulk memory single event upsets have also occurred; these were not unexpected. DSCOVR's primary objective is to provide space weather data for forecasting. There are Earth Science instruments on board as well. JASD will hand over the mission to NOAA to operate in July. A fluxgate magnetometer and Faraday cup are the primary instruments. Secondary instruments are an Earth Polychromatic Imaging Camera (EPIC) that images the sunlit face of

Earth in 10 wavelengths, an electron spectrometer and a pulse height analyzer. The spacecraft carries 145 kg of fuel and has a 2-year design life, and 5-year propellant life. NOAA will maintain its orbit. JASD has NOAA operators currently embedded with the NASA team, and NASA will be providing engineering support after the handoff.

DSCOVR is funded at 21,100K for 2015 and at 3200K for 2016, reflecting the handoff to NOAA. A Space Weather Follow-on contains 2500K in FY16 for researching what's next, and NASA is working with NOAA to determine this. The FY16 budget is meant to maintain and operate DSCOVR, plan and initiate development of the Follow-On program, and formulate life cycle costs for the Follow-On mission that will be included in the FY17 budget. NOAA works closely with the European Organisation for the Exploitation of Meteorological Satellites (EUMETSat) and the United States shares data with them as well. Dr. Maura Hagan commented that L1 data is also important for research. Dr. Clarke agreed that it also was important for models for forecasting. NASA does not make the decision for whether DSCOVR will undergo a Senior Review. Funding beyond 24 months at NOAA for DSCOVR is not in the budget at present. Public engagement for DSCOVR will be handled by Earth scientists, and data will be put up on an existing Langley Research Center public website. Earth scientists will be providing captions.

Jason-3 is an altimetry and global sea surface mission, whose objective is to provide continuity of ocean topography. Jason-3 will be the first NASA launch on a SpaceX Falcon-9; it will also carry some international instruments. The spacecraft is in storage awaiting shipment; the launch vehicle remains on schedule. The budget reflects funding for spacecraft check-out and the handover to NOAA for operations. EUMETSat is also involved in this mission. JPL provided the American instruments, and will stay on for sustaining engineering and reach-back.

The GOES-R series satellite (of R, S, T and U) will be launching on an Atlas V out of the Cape. Its instruments include a lightning mapper, magnetometer, and solar ultraviolet imager. All instruments have been integrated onto the spacecraft bus, and the antenna wing assembly has been delivered for testing and pre-environmental review. It will enter the thermal-vacuum chamber in early May or June. Not all sensors have been built, but long-lead parts have been procured in a block-buy. GOES-S is beginning its build-out. The budget request is $980,800 K in FY15 and $871,800 K in FY16. Asked if there had been a learning curve in building the 4 satellites, Dr. Clarke replied that JPSS did not follow the same procurement and did not have approvals. JASD will try to do similar block-buys with future JPSS satellites, and is continuing to learn from the process.

Launch commitment dates for JPSS 1 and 2 are in the second quarter of FY2017 and first quarter of FY2022, respectively. JPSS-1 will carry an Advanced Technology Microwave Sounder (ATMS), and JPSS-2, an ESD Radiation Budget Instrument. ESD pays for the instrument development and the integration and testing (I&T) onto the spacecraft bus. Estimates of fuel consumption are based on Level 1 requirements from NOAA. JPSS satellites have a mission life of 7 years, and 10.5 years of fuel, however in practice, NASA is factoring in assumptions that the satellites will work longer. JPSS-1 will launch on the second to last Delta II vehicle; a new vehicle must be procured for JPSS-2. On JPSS-1, the ATMS instrument had a number of challenges. In addition, the mission is going through a redesign of amplifiers for JPSS-2. The JPSS-2 spacecraft bus contract was awarded to Orbital ATK, with options for JPSS-3 and

4. All instruments are under contract for JPSS-2. The JPSS Program Follow-On contains some technology development at MIT Lincoln Laboratories, particularly for a nanosat microwave instrument. A Solar Irradiance Data and Rescue (SIDAR) was originally designed to be on a polar free-flyer, but the instrumentation has since broken down. NOAA is now looking for ride share with the Department of Defense (DOD) for Search and Rescue Repeater (SARR) and a related sensor; NASA is no longer responsible for these. The Total and Spectral Irradiance Sensor (TSIS)-1 will fly on ISS in 2017. Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC) is a constellation of satellites that uses radio occultation, supported by multiple agencies and the Taiwanese government. COSMIC 2A is scheduled to launch in May 2016. JASD will be involved with COSMIC-2B, and the U.S. Air Force will provide the first 6 satellites for COSMIC 2A.

Asked how any potential budget underruns were handled, Dr. Clarke explained that NOAA is the ultimate decision authority. NASA goes through monthly reviews jointly with NOAA and responds to NOAA priorities. In total, JASD manages about $3B in satellite missions.

Heliophysics FY16 Budget and Division Update/Heliophysics Subcommittee Report

Dr. Jeff Newmark presented a status of HPD. Magnetospheric MultiScale (MMS) successfully launched on March 12; instruments are turning on and booms are being deployed. MMS is a fundamental physics mission, comprised of four, formation-flying observatories with 25 instruments each, which studies magnetic reconnection in Earth's magnetosphere. The Air and Space Museum has installed a new permanent exhibit on the Solar Dynamics Orbiter (SDO), supplying real-time solar images and pre-programmed movies. Recent highlights in HPD include the 5th anniversary of SDO, which has returned its 100-millionth image. In addition, better understanding of ionospheric "froth" as observed by SDO may lead to improvements in the Global Positioning System (GPS). The sounding rocket program is also going very well.

HPD is overseeing 18 operating missions that share interconnected science goals, including the Solar and Heliophysics Observatory (SOHO), Advanced Composition Explorer (ACE), and the Van Allen Probes. Five missions are currently in development: the Space Environmental Testbed (SET), Solar Orbiter Collaboration (SOC), Solar Probe Plus (SPP), Ionospheric Connection (ICON), and Global-scale Observations of the Limb and Disk (GOLD). In the near term, HPD will be launching $3B worth of missions between now and 2018, including SPP that will fly into the inner corona of the Sun. The highest priority for new missions is to increase the cadence of the Explorer program to every three years. Dr. Newmark hoped to get a Mission of Opportunity (MoO) in 2020, knowing that there are concepts out there waiting for an AO. In the budget, what's changed is support for the Diversify, Realize, Integrate, Venture, Educate (DRIVE) initiative, with an increased budget in 2016 and full implementation in FY19, the first real growth in a decade planned for the Heliophysics research program. The budget also supports a SOC launch readiness date (LRD) of October 2018. The SPP budget profile was confirmed in March 2014, and the mission is well on its way, on cost and schedule, for launch in 2018. MMS is funded for Phase E; the ICON and GOLD budgets are going well. The Cluster mission was not supported in FY15. Funding for cubesats remains the same.

Recent accomplishments include today's Critical Design Review (CDR) of ICON, and continued

development of instruments for SOC. SDO, Interface Region Imaging Spectrograph (IRIS), and the Van Allen Probes are completing their prime missions and will be part of a Senior Review beginning on April 21. HPD is continuing its annual campaign at Poker Flats, launching 1-5 missions per year. HPD also runs the Sounding Rocket Program for the Agency, receiving $53M a year to support the infrastructure, and both Heliophysics and Astrophysics payload. The payloads themselves are funded out of Research and Analysis (R&A) from the individual divisions. The division is trying to grow the research program in general, through sounding rockets, cubesats, and technology development.

The Sounding Rocket Program had no decrease in funding and is being healthily maintained. Budget changes reflect a planned multi-year phasing of budget allocations. Some other variations reflect bookkeeping for non-Heliophysics funds. Dr. McComas noted that the Science Committee has commented previously that these binning practices skew the books, and asked if there were other appropriate places for pass-throughs. Dr. Newmark noted that a better job is being done with this in the outyears. There is strong outyear growth in the Explorer program, as recommended by the Decadal Survey. The FY16 budget appears to show that the directed research and technology line is dropping, however this doesn't affect HPD; it's just another bookkeeping issue. Overall, HPD is very pleased with real budget growth in the outyears. The Guest Investigator (GI) program is increasing as well as a key element of DRIVE. In response to a ROSES (Research Opportunities in Space and Earth Science) elements discussion from the last Heliophysics Subcommittee (HPS) meeting, HPD had considered combining the GI and Supporting Research programs. Having received a recommendation against it, HPD agreed and rewrote the ROSES elements to better differentiate the two programs. Research proposal submission statistics, associated with a change to a two-step structure initiated 2013, indicates increased success rates at roughly 25% (based on step-2 proposals). Dr. Newmark felt that the restructuring is still in an experimental phase.

Heliophysics Subcommittee Report

Dr. Maura Hagan, HPS Chair, provided an update on the subcommittee's most recent meeting in late March, with a fully constituted committee. Dr. Hagan noted that she was stepping down as Chair but will serve as a member for another year. HPS developed two findings, one of which applauds the imminent release of the Heliophysics Science and Technology Roadmap. The final version is online. A second finding applauds HPD leadership on their plan to realize the objectives of the 2013 Decadal Survey for Solar and Space Physics. HPS heard an update from SMD on the HPD Division Director search process and outcome. Four highly qualified candidates were interviewed but no one was selected. HPS developed a related recommendation for consideration by the Science Committee, calling for SMD to take steps to establish permanent HPD leadership in a timely fashion, and to communicate the importance of heliophysics science to NASA and the nation along with assurance that SMD will maintain a distinct Heliophysics Division within SMD. HPS believes that the lack of permanent leadership is of great concern, since it could stagnate the HPD program, lead to missed opportunities, and further impact the morale of the community.

HPS heard briefings on the two-step proposal process and recommended that the process go forward. 2013 GI program outcomes showed a 53% reduction in the number of proposals, however Supporting Research program results were remarkably different, with 5 discouraged proposals ultimately

recommended for selection. The nonbinding nature of the process may result in PIs not taking the step 1 seriously, and waiting for step 2 to present a serious proposal. Dr. Newmark commented that the intent of the encourage/discourage step is to keep selection rates at 25-30%, to reduce the burden on the community. Dr. McComas commented that the process risks cutting out people who have great science to contribute. Dr. Newmark noted that as the process was non-binding, a PI can propose fully after a discouragement. Step 1 proposals are reviewed via mail-in by community members; there is no subsequent feedback. Step 2 proposals are reviewed blindly. Evaluation criteria include compliance, relevance of proposed science, and relevance to division objectives and to the Decadal Survey. HPS has recommended that the two-step process continue, but there was a division of opinion on whether the process should be binding or non-binding.

HPS found that future Explorer AOs should explicitly enable the use of fueled secondary payload adapter fitting (PAF) modules to enable access to parts of space and opportunities, particularly for smallsats and constellations. Dr. Hagan felt the Science Committee should consider this finding as it may have implications across SMD. Dr. McComas recommended that the SC consider this after a future presentation, pending further study of PAFs.

Topics deferred for future discussion for HPS include better distinguishing the H-GI and H-SR elements for ROSES 2016; MMS and/or synergistic HSO science; concern over HPD staffing; and use of airborne platforms. Science highlights in Heliophysics include observations from Solar TErrestrial RElations Observatory (STEREO) A/B data and near-Earth spacecraft, indicating that nearly a third of solar energetic particles originate from the far side of the Sun. Advanced Composition Explorer (ACE) real-time forecasting of coronal mass ejections (CMEs) now provides a half-hour warning for peak intensity of 20 MeV protons. The Van Allen Probes tracked an interplanetary shock through the inner magnetosphere, showing prompt acceleration of electrons. The Time History of Events and Macroscale Interactions during Substorms (THEMIS) mission has discovered that the Earth's magnetosphere can fortify its walls to shield against solar storms; i.e. a physics-driven system is providing some protection from CMEs. Interstellar Boundary Explorer (IBEX) has provided data that resolved some differences with Ulysses in terms of speed, direction and temperature of helium, which is showing that IBEX is in a much hotter part of the universe than measured previously by Ulysses.

Ad Hoc Briefing on Travel Rules

Assistant Deputy CFO Mr. Joe McIntyre led a discussion on travel rules, explaining that the last policy change took place in March 2014, when Headquarters lifted most restrictions. Dr. Lindberg asked what is meant by "exempt from limitations," given that contracting scientists are still being denied travel; when dealing with contractors there seems to be a disconnect in the trenches. Mr. McIntyre was unaware of this disconnect. He stated that it is still required to obtain advance permissions for travel for both contractors/scientists and civil servants, but that Headquarters does not get involved with the center bureaucracy. Headquarters only gets involved in the reporting of how many individuals are traveling and how much does the travel cost; these numbers must be reported, by force of law, to Congress, OMB and the Office of the Inspector General (OIG). From an Agency level, the centers are the ones that require more detail that is being described by the complainants. Dr. McComas asked if it was a NASA decision to include contractors [in the reporting process]. Mr. McIntyre replied that this was a NASA IG

recommendation that was ultimately accepted by NASA. Unless there is a significant reason to non-concur, NASA usually agrees to IG recommendations. Because NASA has a heavy contractor component, it must record how much it is costing NASA. Pre-conference, if spending is more than $500K, it must be reported and published. Post facto, NASA must report all costs. Dr. Robinson asked if centers were over-interpreting guidelines. Mr. McIntyre responded that a management operation for a particular conference does not involve Headquarters decision-making. The programs, mission directorates and centers are the entities that get involved in deciding what scientist goes to a conference. Dr. McComas observed that previously, it was the PI on a contract that determined who went to a conference to present scientific results and the centers didn't get involved. The process has changed to others in NASA now deciding for the PI who should go. He wanted to understand how to satisfy the law while avoiding over-interpretation and such unintended consequences. Mr. McIntyre suggested taking the issue up with the centers. He noted that Headquarters, however, has made a huge communication effort to emphasize the flexibility of the travel rules. As a result, Mr. McIntyre reported that NASA is now sending more people to conferences compared to the pre-sequestration period. Dr. McComas requested copies of this communication for the Committee.

Dr. Lindberg reported having heard that there are no restrictions on the number of contractors that can go to domestic meetings, but that the NASA COTR (Contracting Officer Technical Representative) retains the right to decide who goes to these meetings. Mr. McIntyre was unaware that the COTRs are making these decisions, and reiterated that approval levels are the issue. It must first be determined whether the cost of the conference exceeds $100K or $500K. The Lunar and Planetary Science Conference (LPSC) was unique this year; NASA ended up sending 370 people to LPSC. Prior to sequestration, NASA sent an average of 100 contractors and NASA staff to LPSC. These numbers were confirmed through a vetted data collection process that dated back to 2008, in response to a Congressional inquiry. Committee members expressed skepticism at these numbers. Mr. McIntyre averred that this reporting has been in place since 2010. He described the current manner in which a conference is approved: information is entered into a web platform, after which conference points of contact (POCs) determine how many people across the agency wish to go and what the estimated expense is. Dr. McComas asked if it would be feasible to allow a PI to estimate how many persons would go to a meeting (e.g., an American Geophysical Union (AGU) meeting) and give NASA a good estimate without the expensive process of naming each person months before the abstracts were even due. Mr. McIntyre felt this was feasible, and thought that many of the centers are already doing this. Dr. Lindberg theorized that lower-level denials may not be rising to the attention of Headquarters. Mr. McIntyre agreed that further discussion might be warranted. Dr. Pieters wanted to know what the specific legal requirements were before the Committee made a recommendation. Dr. McComas reiterated a request to obtain particulars on the communication to the centers.

Discussion with SMD Associate Administrator

The Science Committee held a discussion with the SMD Associate Administrator (AA) Dr. John Grunsfeld, who thanked Committee members for their continuing service. He described becoming more overwhelmed with bureaucracy of late. Having testified before the House Science Subcommittee on the James Webb Space Telescope (JWST), he reported that JWST is doing well technically, and in terms of cost and schedule reserves, to get to an October 2018 launch. In addition there is now a much stronger

scientific case for JWST than when it was first conceived. Many exoplanets and dwarf planets have been discovered since the mission's initiation. In response to the scientific community, NASA has essentially completed or is working on all Tier 1 science in the Earth Science Decadal Survey, and is maintaining a relatively high cadence of new opportunities. In PSD, there is now a Mars 2020 caching mission and the beginning of a Europa mission, the top two recommendations of the Planetary Decadal Survey. This year Juno will arrive at Jupiter, and New Horizons at Pluto. In addition to the 2020 rover, three major Mars missions are in development. PSD is doing exceptionally well, and hopes to put a new AO out next year for New Frontiers program. In APD, the Hubble Space Telescope (HST) is doing well and is celebrating its 25th anniversary this year. The Transient Exoplanet Survey Satellite (TESS) is still doing well, strengthening the case for the WFIRST mission. HPD also exhibited an appropriate response to the Decadal Survey, with SPP and SOC on schedule, and a strong suborbital program, including a very promising superpressure balloon which, in principle, can stay aloft for 6 months.

The balance between divisions is designed for some rise and fall, and while SMD is trying to consider new starts, there is still concern at the PI level about the cadence of the smaller missions. Over the last few years, SMD has established a good record for bringing in the smaller missions on schedule and within budget. Dr. Grunsfeld asked the Committee to work with community members to help communicate the science supported by NASA.

Dr. Spence asked whether NASA could facilitate public interactions with the American Association for the Advancement of Science (AAAS), among other organizations. Dr. Grunsfeld noted that NASA holds Lunch and Learn meetings once a month on the Hill, and that most of the NASA leadership participates with relevant societies in this arena. Dr. McSween asked about the continuing role of the Analysis Groups (AGs) under the new NAC infrastructure. Dr. Grunsfeld said he viewed the Mars Exploration Program Analysis Group (MEPAG) and related groups as critical, and had no intention of diminishing the role of the AGs despite the NAC infrastructure change. Dr. Hagan asked about the possibility of a large-scale Heliophysics mission as recommended in the heliophysics Decadal Survey. Dr. Grunsfeld noted that there is no budget for such a mission now, but that good ideas with quantifiable risk are still needed to take advantage of a budget should it become available.

Dr. Robinson asked if SMD could cooperate more with HEOMD in programs such as SIMPLEx (Small Innovative Missions for Planetary Exploration), which are small satellite payloads piggybacked on SLS launches. Dr. Grunsfeld replied that while SLS was maturing, SMD had ongoing discussions with them on science additions, and is still doing this. For SLS in particular, SMD is engaged in discussing the addition of science payloads to Orion test flights. For human-rated test flights, the division working on adding payloads that pose low risk to the crew. The crew vehicle design is still changing. There are some options where science measurements constitute just a co-manifest. Every mission is considered in this way, as all of NASA science is human endeavor. DSCOVR is a good example of acquiring space weather solutions partnered with science measurements to leverage taxpayer dollars. Dr. Robinson commented, in the context of enabling human travel to the Moon, Mars, and beyond, that piggyback missions could address resource and engineering questions, in a program with overlapping goals and objectives. Dr. Grunsfeld noted that the Origins-Spectral Interpretation-Resource Identification-Security-Regolith

Explorer (OSIRIS-REx) mission is a good example of such a mission, as is option B for the Asteroid Redirect Mission, which involves sample return - this concept came out of SMD.

Dr. McComas commented that the budget accounting bins used in HPD tended to obscure the budget. The money for items being book-kept there needs a home and needs management. Can it be handled in JASD as are all reimbursable activities? Dr. Grunsfeld promised to get an answer to that question. Dr. Hagan asked for Dr. Grunsfeld's vision for HPD, particularly in light of the failed effort to find a new Division Director. Dr. Grunsfeld replied that the situation definitely does not reflect a dim view of Heliophysics at NASA. The Sun and heliosphere play a major role in space science. There is enthusiasm (for example, regarding the University of Chicago work) and much to learn on the solar cycle mystery -- the future is strong. The solar cycle is very anomalous; had the Sun not been so quiet NASA would have planned a mission to disable HST. This is now pushed off to the 2030s rather than the 2020s. We are close to understanding the heating of the corona, and would like to understand magnetic reconnection in 2-3 years. This is needed to support humans in deep space. SMD still wants to better understand CME prediction and the Sun-Earth connection, and supports the current plan to carry out science from a strong Heliophysics Decadal Survey. Any idea about a possible merger of the Heliophysics Division with another part of SMD is not true.

Dr. Gaudi asked how APD could reduce the handwringing over selecting large missions versus probe missions, recognizing that JWST is a large commitment as WFIRST gets started. Dr. Grunsfeld recommended preparing for the Astrophysics 2020 Decadal Survey with this question in mind. Do we want a high-resolution spectrum of an Earth-like planet 25 light-years away, requiring a large-aperture telescope? The community should not fear going forward with another great observatory. Are the resources available for something like Inflationary Probe; is there a specific box for probe missions? Maybe the answer is a probe class, which would push off another large mission. These are questions for the community to discuss.

Dr. Pieters addressed the need for small missions, as their frequency and diversity builds the base for scientific enthusiasm, coupled with the larger missions. Dr. Grunsfeld agreed that such things as cubesat missions would be very helpful in this regard.

Discussion

The committee took up potential findings on travel, the HPD Director search, and the two-step process for research proposal submissions that was tabled until additional data could be gathered for the next meeting. Dr. Lindberg suggested that in addition, the Committee consider reviewing the contributions JASD is making to NASA science -- the linkages with the missions -- rather than spacecraft development. Dr. McComas asked that this be addressed in a future JASD briefing to the SC.

Dr. Spence seconded the HPS finding on HPD leadership, as well as the travel issue. Dr. Spergel raised a concern about speculation in the community about selecting a non-scientist to the position, or possibly folding HPD in with another division. There are career choice issues. Dr. Hagan noted that at the HPS meeting, Deputy Associate Administrator Geoff Yoder made the case for great heliophysics science; and that supporting only the selection of a heliophysics scientist was not a unanimous HPS view. Dr.

McComas proposed that Drs. Hagan, Spence, and Lindberg write a recommendation on the HPD directorship. There was discussion that this should include broad support rather than detail.

The committee discussed travel, concluding that they were at an impasse. Dr. Spence suggested the Science Committee make a compelling argument to relax the restrictions while meeting the letter of the law. Dr. McComas suggested that one could ask PIs to estimate numbers as early as possible for upcoming meetings to get through the first part of the process. Dr. Lindberg suggested arguing that simplifying the process will reduce overall cost. Dr. Pieters recommended illustrating savings with explicit percentages.

Joint HEOMC/SC Meeting

The Science Committee engaged in a joint session with the Human Exploration and Operations Committee (HEOC). Dr. Bette Siegel opened the meeting with brief remarks, then turned meeting over to Dr. McComas and Mr. Kenneth Bowersox, Chair, HEOC. Mr. Bowersox identified HEOC members around the room, and said that the importance of the topic was reflected by the large attendance.

Space Radiation Presentations and Discussion

Mars Mission and Space Radiation Risks Overview

Dr. Steve Davison, Program Executive for the Human Research Program at HEOMD, introduced the briefing, a response to a previous NAC request. The Human Research Program seeks to understand, quantify and minimize health risks associated with radiation exposure in space. The current focus is on continuing research and risk mitigation on issues ranging from chronic low dose radiation exposure to acute exposure to solar energetic particles. Work on the Space Radiation Environment includes modeling and prediction data from SMD, as well as information derived from HEO model projections, in-flight mitigation practices, space radiobiology data, radiation transport models, and radiation shielding techniques. Dr. Davison pointed out other individuals in the room with radiation expertise who were available for questions. The NASA programs that address these health risks have been extensively vetted by the National Academies of Science (NAS) and the National Council on Radiation Protection. The program includes more than 70 investigators on the space radiobiology side, outside of NASA. Finally, in support of HEO, programs are critical to provide the best assessments to inform on risks to astronaut health in a Mars environment, and to mitigate risk to be as low as possible.

Dr. Davison began the briefing on Mars Mission and Space Radiation Risks. Thus far NASA has identified the specific risks and has medical standards in place to mitigate most of them. All evidence, research gaps, and tasks to address the research gaps are available online (http://humanresearchroadmap.nasa.gov). To date, no mission-stoppers (i.e. no risks for death, serious or permanent injury, or loss of performance) have been identified. The biggest challenge for human crews are additional exposure to radiation and the risk of radiation-induced cancer. The Agency will accept some level of crew health risk for a Mars mission, but that risk will continue to be reduced through research and testing. Dr. McComas asked how the program kept track of major drivers, such as the possibility of large solar flares and effects of shielding thicknesses. Dr. Davison replied that trade-offs would be anticipated, but crew health and safety are number-one priorities, as would be seen in the briefings to follow. Solar energetic particle (SEP) events can be managed through shielding and real-time

dosimetry; overall SEP exposures are thought to amount to about 15%. The most challenging issue is the chronic low dose of galactic cosmic rays (GCRs), which has the longest-term implications down the road.

Mr. James Voss commented that according to the presentation, the only risk not mitigatable by 2028 was the radiation risk. This is an important point; that we can't in fact meet the current cancer risk standard right now.

Dr. Davison catalogued a number of other human spaceflight risks: bone loss, cardiovascular (CVS) and central nervous system (CNS) issues, and visual alterations. Distance from Earth is also a factor, as are communications, closed environment, and behavioral issues associated with isolation and long-term confinement. The Human System Risk Board identifies 30 canonical, non-rank-ordered risks associated with space flight. The risks that are considered to be most significant for Mars missions are chronic space radiation exposure (acute risk is not included here because it is considered adequately mitigated), visual alterations, renal stones, CO_2 levels, inadequate nutrition, and the lack of ability to medically treat any issues. Medical standards are in place for physiological systems, and crews should be able to meet standards for duty, while allowing for some bone loss within a reasonable range. Meeting the permissible radiation limit on a Mars mission, however, will be challenging; this is driving a lot of current activities in terms of research and mitigation. GCRs present issues with penetrating protons and heavy nuclei; SEPs are a little lower energy. This is a classically an SMD research area in modeling and prediction.

Risk is broken into several categories, including carcinogenesis, acute radiation, and degenerative effects in CVS and CNS. NASA has generated a model that is used for assessment of lifetime cancer risk. With respect to acute exposure, there is now a mature model and mitigation scheme. Research is underway on non-cancer effects. Once cancer risk is controlled, all other areas are controlled at this time. Mars missions may expose crew to levels of radiation that will raise lifetime cancer risks and cause undefined harm or degenerative changes in the CVS and CNS. Risk assessment is based on 900-day conjunction class missions, including 500 days on the Mars surface. All risk calculations have been vetted by the 2012 NASA Space Radiation Cancer Risk Model, which in turn has been evaluated by NAS. Models take into account many variables, including shielding, as well as secondary particles generated by shielding materials. GCRs above 500 MeV are of great concern. Dr. Spergel noted that during the Planck mission in 2011, there were more than triple the number of 500 MeV events than had been predicted by models.

Post-mission cancer risk by age and sex has been calculated. For the NASA astronaut cohort, this is calculated at 16% for males, 12% for females; post-mission to Mars, this increases to 20% for both sexes. There is a two-fold difference in risk between solar maxima and minima. According to the American Cancer Society, the average population has a 20% lifetime risk of developing cancer. Current risk models predict that of 100 astronauts exposed at solar maximum, 21-23 would die of cancer instead of 16 over their lifetime; life expectancy is reduced by 15 years for those exposed to the radiation. Dr. Davison cautioned that it is challenging to use a population-based risk model to estimate risk for any individual.

To minimize exposure, NASA is integrating research across the agency, and looking at countermeasures such as nutrition, intervals of full-body surveillance, in-flight crew monitoring, and dosimetry, while receiving advice from external panels on how to proceed. NASA is working across all phases of the Mars

mission to minimize the radiation health risk, including personalized cancer screening and shielding. Research is ongoing at the National Space Radiation Laboratory (NSRL). Based on current mitigation plans, Mars mission health risks have been identified, and medical standards are in place to protect crew health and safety. NASA will have to develop a concept of operations to minimize exposure. Dr. Spence commented that the NSRL is always under a concerning amount of stress. Dr. Davison noted that NASA has a very good partnership with the Brookhaven facility, which is now providing mixed-field particles for more realistic simulations.

Health Standards Decision Framework

Dr. David Liskowsky noted that even with current mitigations, a crewed mission to Mars may not be able to meet standards now in place. Consequently, NASA's Office of the Chief Health and Medical Officer (OCHMO) requested that the Institute of Medicine's (IOM) Committee on Aerospace Medicine and Medicine in Extreme Environments to produce a report on policies that should be adopted.

The IOM Report makes three recommendations based on ethical principles and responsibilities. A fourth recommendation was in the form of a decision-making framework that could be used by NASA to address a mission where a medical standard cannot be met. It is important to note that from a medical perspective, the first principle is to avoid harm to crewmembers, while also recognizing that some of these principles must be balanced. The idea is to execute a continuous learning strategy. In order to accept risks and justify decisions, NASA must commit to continue examining mitigation strategies. Liberalizing health standards or establishing a new set of standards for space exploration are not deemed to be acceptable. Criteria for granting exceptions range from the nature of mission, health risk in context of other risks associated with the mission, committing to fully informed risk, and additional responsibilities if the additional risks are to be accepted (e.g. increased monitoring, Agency-funded health care).

The report also provided a multi-level decision-making framework for making exceptions. OCHMO has concurred with the recommendation to accept health standards that would be used only "under very limited circumstances" and would not represent a standard medical waiver. OCHMO is in the process of developing an implementation plan that will likely be brought before the NAC for approval. The committees debated what constituted a medical waiver. Dr. Liskowsky noted that in the framework, a decision by the NASA Administrator would be used, and not a standard medical waiver. Chief Medical Officer, Dr. Richard Williams, provided some clarifications for a waiver for exposure vs. a true medical waiver, explaining that there is no current tradition for an exposure waiver, thus the risk decision becomes a policy decision. It will be a year or so before OCHMO has developed a mature set of procedures. Asked whether NASA would ask for volunteers, in the case of significantly high risk, Dr. Liskowsky replied that such a case would involve informed volunteerism. Dr. Longnecker asked if any alternative approaches had been considered with regard to crew selection, with the awareness that certain populations vary in terms of cancer risk. Dr. Liskowsky responded that this was beyond the scope of the IOM report. Dr. Pieters asked what responsibility NASA was prepared to take on in response to the additional risk. Dr. Liskowsky replied that the Agency would provide health care and long-term monitoring to the exposed astronauts corps, with specifics to be determined. Dr. Williams added that NASA has been working for over a decade to obtain Congressional and legislative approval to provide extensive health care for astronauts. Dr. McComas noted that the NAC would be considering a finding related to lifetime health

care and in space life insurance for astronauts.

Space Radiation Environment
Dr. Chris St. Cyr introduced the subject, noting the three primary sources of space radiation: trapped radiation within the Van Allen belts, SEPs, and GCRs. SEPs are modulated by the Sun's activity and are cyclical. GCRs are high when Sun activity is low and vice versa.

Solar Energetic Particles
Dr. Allan Tylka presented a review of known SEP radiation hazards. The current solar cycle has been anomalous both in terms of SEPs and GCRs, this cycle is different from what has been seen historically. Single-event upsets (SEUs) recorded at SOHO have increased by 21%, representing a direct measurement of GCRs at L1. While GCR levels have become more severe, episodic SEP radiation has become less severe and frequent. It is possible that solar cycle 24 is the "new normal."

A Space Radiation Risk report was published in 2007, concluding that he SEP hazard is greatest when GCRs are lowest. However, ground-level events have been detected at solar minimum. SEP radiation hazard is largely due to protons, but is also associated with heavy ions, which may have subtle physical effects. Biology is the biggest uncertainty in assessing the SEP radiation hazard for astronauts, and is hard to translate to cancer risk. An early warning of SEP hazard is needed to allow time to shelter, e.g., when on an extravehicular activity (EVA). Types of early warning models are experience-based (NOAA) and physics-based. Monitors can give warnings in terms of minutes.

Some of the largest SEP events recorded since 1956 were very large events that would have required substantial amounts of shielding. SEP proton-energy levels above 100MeV require shielding or shelter. The solar proton energy spectrum for designing a shelter for astronauts, depending on the spectral range, varies in estimating shielding over a 30-day period. A comparison of SEP events of at least 30MeV in the years 2-7 of solar cycles 22-24 has been made. In cycle 24, the slope of event diminution is steep; in terms of SEP radiation, solar cycle 24 is much less severe in terms of SEP events than in the two previous cycles. Comparisons to cycles 20 and 21, however, indicate the SEP pattern needs a little more study; lesser SEP severity may not be an ongoing trend. Very large events have not been seen in the current solar cycle. If these very big ground-level events (GLEs) have disappeared, shelter or shielding would not be required or would be greatly reduced. Dr. Spence pointed out that there have been several recent, large events on the other side of the Sun, many of which were quite energetic.

Based on sunspot number, for which there is a long historical record, it has been observed that when sunspot numbers are low, the chance of a large SEP event is low. The trend of low sunspot numbers seems to suggest that there might be low SEP activity for many decades. For example, during the Maunder Minimum, there were essentially no sunspots from 1645-1715.

Comparison and Validation of GCR Models
Dr. Tony Slaba presented an overview of GCR models, beginning with a background on exposure analysis, shielding, environment, and physics models that have been funneled into radiation transport models and to risk models. The GCR environment is omnipresent in space, and fluctuates between solar

minima and maxima. GCRs include protons, alpha particles, and heavy particles. At very high energies, there is no difference between solar minima and maxima. As one goes to lower GCR energies, however, the solar effect increases greatly. The Badwhar-O'Neill (BON) model of GCRs is used at NASA as input into radiation transport codes for vehicle design and astronaut risk analysis. The BON model has had several revisions, all based on a fundamental framework. Models have been developed and validated using SMD and other science data over the past four decades. 82% of available data comes from Advanced Composition Explorer (ACE) and the Cosmic Ray Isotope Spectrometer (CRIS). Models do agree reasonably well at high energies where effects of solar modulation are less pronounced.

Human exposure quantities behind shielding are in good agreement if updated GCR models are used. NASA's radiation transport code is called HZETRN (High charge(Z) and Energy TRaNsport), a highly efficient method compared to Monte Carlo methods. NASA's code takes one minute to run vs. 3 years CPU time for a Monte Carlo simulation.

For astronaut risk assessment, end-to-end model results are normalized to area dosimeters on the ISS. Cancer risk models (for something like a Mars mission) require more detailed information than ISS area dosimeters provide. Direct model evaluation (without normalization) is used in validation, resulting in higher uncertainties (10-50%) than normalized validation (15%). MSL's Radiation Assessment Detector (RAD) instrument has allowed for comparisons between NASA models and Mars surface measurements; in this case, substantial differences have been seen for some ion species. Models for mission planning and shield design have used historical cases as design cases. Models are now moving to a more probabilistic approach, allowing estimates to be made within a certain confidence interval. At present, there is roughly a factor of five variation in predicting relatively short-term solar activity, with obviously much larger error over a longer period.

While design will require a real-vehicle geometry, yet to be determined, the intent is to follow a risk/mass approach, which requires knowledge of an end-to-end mission. Passive shielding is not expected to be deployed for GCR protection. Adding more mass per square centimeter in shielding elements may not be an improvement. There are no real answers here. It is thought that about 15-20 g/cm^2 of shielding around a vehicle is needed to protect against GCRs, nominally.

Implications of the Worsening GCR Radiation Environment

Dr. Nathan Schwadron presented evidence of a worsening GCR radiation environment, based on direct measurements from the MSL RAD instrument and the Gamma Ray Telescope. During the recent protracted solar minimum (cycle 23) and "mini-maximum" (cycle 24), instruments have observed decreasing solar wind, flux, pressure, magnetic field strength, all of which lead to higher levels of GCRs. There is a long-term record of magnetic field strength and sunspot number correlations, including data from OMNI and from ice cores. This current cycle that has come out of the blue underscores that we have a very poor predictive ability with regard to the space environment.

Based on the most recent observations, it appears that we could be heading into a Dalton-like minimum, a period of activity that lies somewhere between the era we had recently and the Maunder minimum (1645-1715). If we are moving toward a quiet period, GCRs will only get worse. A combination of the Cosmic

Ray Telescope for the Effects of Radiation (CRaTER) concept of operations, which simulates radiation doses received by the body, and observations from ACE and CRaTER, predicts higher level of dose rates as cycle 24 progresses. Modeling is based on slab turbulence plus a force-free model, similar to the BON model. A longer-term trend deduced from the observed heliospheric magnetic field, and ACE/CRaTER data, is that GCRs will be an increasing hazard. The Earth may well be headed into a long period during which the Sun will be very quiet. Based on the 3% risk for exposure-induced death and calculated "allowable" days in space—for a 30 year old male or female—at given shielding robustness levels, the trend is that there will be fewer allowable days in space as we move toward 2020.

PREDICCS, an online system designed to provide the community with a near-real-time characterization of the radiation environment of the inner heliosphere, shows a low probability of SEP events in cycle 23-24. Compared to the total radiation dose-equivalent measured by RAD, RAD saw next to nothing when compared to historical SEP events. Implications of the worsening GCR environment point to the need for more direct observations with which to validate models, and for improved understanding and predictability of SEPs. Dr. Robinson commented that it is difficult to make predictions because "n" is so small; this will require hundreds of years of data. Dr. Spence noted that one can either wait, or look to groups that are studying the geological record as a proxy for large events. Dr. Spergel added that Kepler data on star variability also could prove to be valuable.

Emerging GCR Data from AMS-2

Dr. Veronica Bindi presented a briefing on the Alpha Magnetic Spectrometer-2 (AMS-2), a cosmic ray detector currently located at ISS. AMS uses detectors commonly found in accelerators, as well as many different redundant techniques to identify cosmic rays and particles. Four years of AMS data corresponds to 60 billion events. The main objective of AMS-2 is to search for dark matter in space; i.e. it is looking for products of particle annihilation. AMS-2 measures GCR spectra up to iron, and has 7 independent charge measurements. The AMS group at the University of Hawaii is studying the low energy part of the AMS-2 data spectrum; its main goal is to provide NASA the monthly phosphorus/helium/carbon P-He-C fluxes measured by AMS-2. From May 2011 to November 2013, AMS has observed a flux in phosphorus as a result of short timescale solar activity. Compared with ground-based monitors, proton fluxes have been found to be well correlated. Twenty different events have been observed. AMS-2 is the largest SEP detector ever flown in space, and the SEP spectra measured by AMS-2 covers the highest energy range of SEPs. AMS data combined with other instruments at low energy will provide a baseline for SEP modeling. The monthly proton analysis is currently being refined; AMS will provide this data through 2019. Dr. Spence asked how the data is being made available. Dr. Bindi remarked that there has been a delay in release, as much manpower is required, but agreed that the open access policy has come up against a long tradition of closed data. Dr. McComas commented that the Science Committee might want to take up the issue of timely data access at a future meeting.

Radiation Health Risk Projections

Dr. Eddie Semones, Space Radiation Health Officer at the Johnson Space Center (JSC) provided a briefing on health risks associated with radiation exposure. He noted that NASA participates with the Space Radiation Analysis Group (SRAG), which supports the Flight Surgeon Council, coordinates with international partners and crew, and uses real-time telemetry for daily space weather analyses. SRAG also

maintains continuous linkage with NOAA sensors, and represents many years of knowledge. Congress also chartered the National Council on Radiation Protection and Measurements (NCRP) to guide Federal agencies on radiation limits and procedures.

Dr. McComas commented that some mitigations may drive very large resource implications (e.g., high mass for vehicles), and asked how these considerations are funneled into requirements. Dr. Semones replied that there is a draft requirement specific to stowage and crew position that is meant to take advantage of higher shielding ability during a 30-day mission. The requirement was based on an historical event (August 1972, between Apollo missions 16 and 17) and short-term exposure limits, while providing for a dose that did not violate a career limit for radiation exposure. Dr. Tylka added that there was concern about worst-case environments and insufficient data, while recognizing that engineers still need to study this phenomenon. Dr. McComas noted that he was referring specifically to assumptions that support a statement of mitigatable risks.

Dr. Semones detailed sources of exposure, including GCRs, solar particle events, Mars surface environment, medical, aircraft operations (noncommercial), and other prior exposure. NASA-relevant NCRP reports include a list of issues on genetic susceptibilities, recommendations for low-Earth orbit (LEO) missions, and radiation protection for space activities. NASA permissible exposure limits (PELs) are based on 95% confidence intervals of a risk of exposure-induced death (REID) of less than 3%. This is considered a conservative estimate and is intended to account for uncertainties inherent in risk projection models. Short-term dose limits address clinically significant non-cancer health effects, including performance degradation. Career dose limits are related more to the risk of cataract formation, and damage to the CNS and CVS. Differing acceptable doses have calculated for each organ system, and anatomical element, such as the lens and skin.

Cancer risk is a major driver for PELs. Japanese atomic bomb survivor cancer incidence is used as a basis for risk modeling; research results support the development of an integrated risk model with acceptable uncertainty for exploration missions, while recognizing that these uncertainties can be large in this model. Dr. McComas asked how these uncertainties are accounted for. Dr. Semones replied that Monte Carlo simulations of how uncertainties are distributed were used to determine this. Dr. Spergel commented that atomic bomb data are not considered adequate, and that other data (e.g., from Iran) might be better suited for models. Dr. Semones felt that the model in use is based on a pretty comprehensive analysis. The NASA Space Cancer Risk model was reviewed by the NRC in 2012, which noted the better health profile of astronauts (typically never-smokers) tended to decrease the basic inherent risk as compared to the average U.S. population (calculated as 20%). The risk model uses information from terrestrial research, space radiation research, and epidemiological data. Age- and gender-specific risks are also taken into account.

GCR dose rates in free space, as expressed as a NASA-effective dose, are 1.36 millisieverts (mSv)/day. The number of safe days at both solar minimum (higher GCR, lower SEP) and maximum (lower GCR, higher SEP) are calculated on the basis of this dosage. Acute radiation effects from a solar particle event (SPE) are well known; nowcasting needs for HEOMD's oversight of the ISS comes from many NASA assets, including Geostationary Operational Environmental Satellites (GOES), STEREO, ACE, and

SOHO. ISS operational instruments provide alarms and dosimetry sensors. The radiation flight controller sends warnings to management and flight control team, and ensures that the radiation monitoring system is available. ISS also uses a multi-purpose crew vehicle (MPCV) radiation monitoring concept that uses distributed detectors; during events, crew are relocated in stowage areas.

Space Radiation Research and Technology for Risk Mitigation

Dr. Lisa Simonsen presented a briefing on the space radiation problem from a biological perspective, addressing the source of large uncertainties in predicting effects. Heavy ions are qualitatively different from x-rays or gamma rays, on which most epidemiological and dosimetric understanding is based. Currently there is a Space Radiation Radiobiology Research Plan, which has been externally reviewed by NAS, NCRP, and SMD. Seven NASA Specialized Centers of Research are working in partnership with SRAG.

Mitigation approaches for exposure include determining the time in the solar cycle, increasing accuracy in risk quantification and uncertainty reduction, viewing crew selection in terms of age, gender, lifestyle, and genetic sensitivity, and carrying out research on biomarkers, biological countermeasures, and radiation shielding. The majority of biological research is performed at Brookhaven NSRL, which simulates the space radiation environment, including high-energy ions. NASA has a contract in place with NSRL to upgrade a GCR simulator, to provide a mixed field, high-energy capability. Carcinogenesis risk assessment focuses on assessment of radiation quality and dose-rate effects on cancer processes, and understanding enhanced aggression in high-energy nuclei (HZE) (i.e. GCR-exposed) tumors. Major findings include a low relative biological effectiveness (RBE) for HZE-induced leukemia, evidence for increased aggression of HZE-induced tumors, and distinct gene expression in tumor types induced by radiation. There have been major findings on CNS risk in rodent models that indicate the possibility of HZE-induced cognitive dysfunction, as well as acceleration of disease in Alzheimer's mice.

A committee member commented that the CNS finding contradicts a previous statement that there are no showstoppers due to radiation exposure. Dr. McComas commented that we do not know enough about CNS risk at this time to say whether it is a "mission showstopper." Dr. Simonsen noted that there are mitigation plans in place to address these issues. Dr. Davison added that the NCRP has judged that the current data are insufficient, and that NASA doing due diligence on research.

High doses of low linear energy transfer (LET) radiation (> 5 Gy) have been seen to increase risk of cardiovascular disease (CVD) later in life. Thus the CVD research focus is on understanding and quantifying risk, work on identifying the disease spectrum, and validating surrogate biomarkers. Biological countermeasures research (BCM) is studying major cancer pathways, (telomerase, p53 oncogene), the use of anti-inflammatories and antioxidants, clinical therapies for acute syndromes (e.g., Neupogen for acute radiation syndrome), and sleep and exercise countermeasures. There is a special topic in the 2015 NASA Research Announcements (NRA) toward biological countermeasures against cancer. There is also an interagency group -- Radiation Bioterrorism Research and Training (RABRAT) -- that is sharing information on these subjects. The National Cancer Institute (NCI) and National Institutes of Health (NIH) are also expressing some interest in these studies.

Radiation tools for design, analysis, and optimization include Space Radiation Transport Codes that are used to quantify a mixed field environment at Mars, and on spacecraft to Mars. An updated HZETRN model will be released in December of this year. STMD has initiated a game-changing GCR thick shield project that will be tested at NSRL. Superconducting technology is being considered for active radiation shielding. The Solar Particle Event Storm Shelter Technology Maturation program is researching reconfigurable logistics concepts, such as the use of water walls and pantries in the crew quarters. Vehicle optimization will be refined as trade studies progress. Space radiation remains a major challenge to exploration, and will ultimately require an integrated strategy to enable human exploration at Mars. Asked how mouse models translate to humans, Dr. Simonsen noted that mouse models are pretty good for cancer studies. NASA is still looking at appropriate animal models for other disease processes, and will be advised by external advisors moving forward. In response to a question about active shielding strategies, Dr. Simonsen replied that superconducting field strengths and locations relative to the human body are taken into account when considering their use.

Public Comment

Ms. Lora Bailey, NASA JSC, stated a concern in the connotation of some cited statements from the original presentations, such as "There are no crew health risks at this time that are considered 'mission-stoppers' for a human mission to Mars," and "The most challenging medical standard to meet for a Mars mission is that associated with the risk of radiation-induced cancer." She also commented that among a list of in-flight risks mentioned, there was no mention of in-flight performance risk due to possible cognition or CNS concerns, and posed the question: Doesn't the cognition/CNS concern fit in this list? She indicated that although she understood why they are representing the material in this manner as quoted, she has a big-picture concern that these quoted statements could be misunderstood and/or misinterpreted by a general audience. Ms. Bailey also suggested that there be some consideration to changing the language from stating "there are no crew health risks at this time that are mission-stoppers" to something that indicates that clear plans and risk-reduction efforts are in place which hope to show no crew health-related show stoppers, but that these efforts will need to be concluded over time before we are able draw formal conclusions. She also emphasized the significance of the language and in the messaging of this very carefully and consistently to all our NASA centers as well as to the public.

Wednesday, April 8, 2015

HEOC/SC Discussion

The HEOC and SC re-convened to discuss the previous day's presentations on space radiation hazards. Dr. Siegel opened the meeting. Dr. McComas noted that the meeting would be divided into three segments. For the first half hour, he would give all of the members an opportunity to make comments about what they had heard the previous day. For the second half hour, they would split into two cross-Committee groups to work on developing the findings and recommendations. The third half hour, everyone would get back together for presentation of proposed findings and recommendations. The following suggestions on possible findings and recommendations were offered.

1) Provide statements on what the group heard the previous day, e.g., good presentations, radiation and mitigation efforts on track, a need to continue research and follow the process to identify risks, and stay alert for things to watch for.

2) Develop a general finding; e.g., the HEO and SC Committees have been impressed with the good work being done in HEOMD and SMD. Dr. McComas indicated that he would like to comment on that for the NAC, and he requested that the groups be specific.
3) Dr. Bowersox suggested that the groups start with a finding, then see if it makes sense to do a recommendation.

For the first half hour, the HEO Committee members and SC members offered their comments. Mr. Voss commented that he felt like everyone was saying radiation is a problem, after making an initial statement that it was not. He thought the message ought to be that radiation in deep space for long-duration flights is still a real problem, and that much good work is being done to solve the problem. Dr. Pat Condon noted that a tremendous amount of work was going on to understand the magnitude of the problem, and while the effort is commendable, he felt that NASA should be prepared for the possibility of not being able to mitigate all the risk, but to not necessarily stop the show. Dr. Robinson commented that he would have liked to have seen a presentation on engineering solutions to hazards, or the current state of the art on how to engineer something affordable. He also seconded the thought that space flight is inherently hazardous and may require volunteerism. Dr. Green noted that it will be difficult to make predictions about extreme space weather events, and that one also can't make confidence interval interpretations with any surety when carcinogenesis is still not well understood on the biological level. Real experiments will be needed to measure the environment between here and Mars.

Dr. Gaudi commented that many of the uncertainties seem to be based on solar uncertainties, and wondered if astrophysical science could be brought to bear on these problems. Ms. Shannon Bartell of HEOC pointed out that in its ethics presentation, NASA presented a classical waiver acceptance process to deal with astronaut health risk. She felt that this process must be clearly identified to avoid the perception that NASA is hiding something under the rug. As far as research goes, she was pleased to see that NASA is doing the right thing in trying to understand the risk. Dr. Pieters recommended that NASA openly acknowledge the risks of space exploration. Dr. Spence observed that the presentations had demonstrated a deep appreciation of the issues and the need for an integrated approach, but he felt that in the larger community, there may not be a similar appreciation. Therefore the subject begs for broader and more regular engagement with the larger communities that are doing relevant work, including engineering.

Mr. Bob Sieck suggested a public education campaign on these issues, to be well up front in the process. Dr. Michael Lopez-Alegria noted that radiation hazard and event prediction constitute a difficult problem; the error bands are gigantic. If it is accepted that this a worthy endeavor, NASA may want to recommend a codified, post-career health care program for astronauts, just as the Department of Defense cares for its veterans. Dr. McComas noted that there is already a finding that the NAC would consider on this topic. Dr. Robert Kirshner was impressed with the synergy between the scientific work and biological research, and felt it would be good to have a plan to obtain the necessary data to make an intelligent assessment. He made several points: first, missing from the discussion was the distribution of event sizes for the Sun, and stars similar to the sun; the study of sun-like stars should be folded in to the process. Secondly, the GCR study using AMS-2 data is a study of intrinsic interest, and can help to make the biological basis of hazard assessment more firm; there should be a longitudinal study of astronauts and their histories of

exposure. Finally, shielding studies and secondary particles are only based on computation; these studies must be complemented with experimental work. Dr. McSween commented that not everyone is physically equipped for long-term space excursions, therefore NASA can't afford to be politically correct in deciding who has the right skills and/or biology to go to Mars. Dr. Hagan observed that space radiation is a big, complicated, interdisciplinary problem that needs far more work, and would benefit from an integrated approach. She echoed Ms. Bartlett's comments on public engagement, and thought the focus should be on what NASA ought to be doing rather than changing the language (i.e. "mission stoppers"). Mr. Holloway was impressed with both the quality and scope of what was heard. In his opinion, the key question is: Is the community working on the right things? He suggested that the Committees focus on what NASA is not doing that it should be doing. Dr. Lindberg felt the presentations had been appropriately thorough; in particular the OCHMO presentation on ethics questions was well done and useful. He echoed Dr. McSween's comments on crew selection, and added that the continued revolution in understanding genomics may factor more into these decisions in the future. Dr. Leroy Chiao emphasized the importance of a long-term care program for astronauts, to answer questions on shielding, or other possible avenues to explore with regard to protecting crew. Dr. Longnecker commented that there is a huge amount of work going on in human research that is addressed by other committees; longitudinal studies of astronaut health are in fact ongoing. He felt that initial briefing comments on "mission stoppers" should be clarified, and recommended that the committees hear more about where space weather and biological aspects come together; these areas must be closely linked. Dr. Running asked whether nutrition needs were known for long-duration campaigns: is this a real issue or a no-brainer? What about immune effects? Mr. Bowersox noted that there is similar work going on in nutrition, it just was not discussed. Dr. Jeff Davis, a Chief Medical Officer (CMO) from JSC noted that the program tracks and monitors 30 key risks; today we still exceed the GCR risk for long-term health, but a long-duration mission is still feasible in terms of short-term SEP risk.

The committee broke into two groups to draft findings and recommendations, and the joint meeting adjourned at 10:00 am.

<u>Planetary Science FY16 Budget and Division Update/Planetary Science Subcommittee Report</u>
Dr. James Green, Division Director of the Planetary Science Division (PSD) provided a briefing on division activities.

Dr. Green addressed two actions that had arisen from discussion of PSS findings at the January 2015 Science Committee meeting. First, in response to a request for support of an NEO survey, he cited explicit language in chapters 4 and 10 of the Planetary Decadal Survey that supports such a mission for hazard mitigation. In addition, the NASA 2005 Authorization Act has called for discovery, characterization and hazard mitigation of 90% of the 140m+ NEOs in 15 years. Assets such as the Large Synoptic Space Telescope (LSST) and the Pan-STARRS telescope are being used to carry out this action, but it will not be possible to accomplish this task by 2020. A dedicated NEO Survey will allow precursor robotic missions to small bodies that accommodate both HEO and science goals. Secondly, in response to a recommendation for bringing a science representative to the LRO team, HEOMD representative Ben Bussey is now on board.

Planetary science missions over the last year include a number of significant accomplishments. Instruments have been selected for the Mars 2020 rover mission. NASA is cooperating with the ESA Rosetta mission (with 3.5 instruments) and the Hayabusa-2 asteroid sample return mission. Comet Siding Spring was observed by orbital and surface assets at Mars in October 2014, and a Europa instrument step-1 selection will be held in May of this year. In 2016, the Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSIGHT) mission will land on Mars, and Cassini will move into Saturn's ring system. The Dawn spacecraft has arrived at Ceres, where its ion engine is being used to lower into orbit around the asteroid. By April 23, Dawn will be in an orbit of around 13,000 km, where it will begin to take imagery and to characterize the body's rotation. The latest image was taken on February 19 at 4 km/pixel. Ceres' bright features will be resolved, possibly revealing water emission, as observed by Herschel last year. A heavily cratered (older) surface and basins that contain few craters (younger) are now being seen.

MESSENGER has run out of hydrazine, and is doing a clean-up burn with helium to get to an altitude that will go through solar conjunction; the plan is still to observe Mercury at very low altitude while the orbit degrades. The spacecraft will probably descent to Mercury before April 30. New Horizons will be flying through the five-moon Pluto system in July. Dr. Green presented a series of recent long-range images that clearly show Pluto-Charon as a binary planetary system in which both bodies co-orbit. The New Horizons spacecraft will be trying to navigate between Pluto and Charon, and took an operations/navigation shot in January. Only the northern hemisphere of Pluto will be seen during the four-hour flyby, but all of the moons will be imaged. Atmospheric data will also be obtained for Pluto. After Pluto, NH will encounter a Kuiper Belt Object (KBO) sometime in 2019. Two KBOs about 50 km in diameter are being considered as the most likely candidates.

The PSD budget for FY15 is roughly $1.4B, well above the President's Budget Request. Congress approved additional money for NEOs, support for a healthy Discovery program, and enhanced R&A. In addition, $100M for Europa studies was included, as well as adequate funding for technologies to develop radioisotope power systems, the re-start of Pu-238 production. FY16 is set at $1.361B; unlike previous fiscal years, the outyears show an increase in funding. This gives PSD an opportunity to get Europa on the road to formulation, for a launch in the 2020s. There is also funding for a New Frontiers Announcement of Opportunity (AO), planned for September 2016, and for the development of Stirling engines. LRO and Opportunity are not funded in the 2016 budget, but PSD is going to reassess funding for them for as long as possible. There is $50M for NEOs in FY16. The budget also allows PSD to finish InSIGHT and the Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer (OSIRIS-Rex), and to keep its commitments to ESA's BepiColombo, ExoMars, and the Jupiter Icy Moons Explorer (JUICE).

The Discovery program now has a $450M cost cap, excluding the launch vehicle (LV) and Phase E funding. New Frontiers has an $850M cost cap, also excluding LV and Phase E. Discovery includes MESSENGER, Dawn, LRO, Strofio, and InSIGHT. The New Frontiers program includes New Horizons, Juno, and OSIRIS-REx. Dr. McComas commented that excluding Phase E from the cost cap encouraged competitors to "kick the can" into Phase E; people are encouraged to propose cheaper-to-build, expensive-to-operate missions.

Recent observations at Mars indicate that according to the deuterium:hydrogen ratio at the polar cap, Mars has lost an ocean's worth of water over its history. The Mars Atmosphere and Volatile Evolution (MAVEN) mission has detected an unexpected large, diffuse, ultraviolet aurora. Accommodation studies of instruments for the Mars 2020 rover have been completed, and a variety of instruments from international partners will be deployed on the rover. HEOMD and STMD are contributing the Mars Oxygen ISRU Experiment (MOXIE) instrument, an in-situ resource utilization (ISRU) demonstration that will extract carbon and oxygen from the atmosphere. There is no radiation monitor planned for the 2020 rover. Curiosity has fuel for the next 10 or 15 years, and does have a radiation monitor. Dr. Lindberg asked for a comment on methane and frost accumulation. Dr. Green replied that methane levels have been measured at above background for 100 or more days; it is clearly Mars methane, and not terrestrial. The current thinking is that the methane is local, and is not being transported by winds.

The Europa Clipper concept, a multiple flyby mission, is in its pre-formulation phase. Currently, it is trying to verify the existence of plumes at Europa, to determine how many passes should go through the plumes.

Planetary Science Subcommittee Report

Dr. McSween gave an update on the latest PSS meeting, and brought forward three findings to the Science Committee for possible action. Firstly, PSS has reiterated its finding that raising NEO characterization to an Agency-level priority would be important from both a scientific, planetary defense and human exploration perspective. This finding had been tabled previously. An Agency-level effort could greatly expand the knowledge of reachable asteroids for HEOMD, and for science priorities identified in the Decadal Survey. A second finding regards Discovery and New Frontiers AO language for sample return missions, stating that 75% of returned samples should be preserved for further study. In light of new analytical technologies, PSS finds that this wording should apply to both Flagship and human missions that return samples, and characterizes this as a recommendation, not a finding. Third, PSS encourages NASA to consider innovative ways to encourage more international development, and pursue these avenues more aggressively.

Other PSS findings include a concern that the core science priorities of Mars program are getting subsumed by HEOMD; applause for the impending NRC study on the reorganized R&A program; support for Extended Mission (EM) funding for LRO and Opportunity if the budget allows; encouragement for continued multi-mission radioisotopic thermal generator (MMRTG) and Stirling engine development; support for the increase of the launch cadence of Discovery from 36 to 24 months; and technology development for instruments in extreme environments. Lastly, PSS had a finding about the removal of the Analysis/Assessment Groups (AGs) from the NAC infrastructure, coupled with a recommendation that the functionality of these groups continue, to voice community concerns. Dr. Gaudi added, as an additional concern, that the AGs no longer report up the line. Dr. Green noted that in the SMD approach to new rules, he would expect the AGs to apply for a conference grant in order to meet, then each subcommittee would have an open public comment period during which meeting results will be discussed. Dr. McComas noted that the Science Committee should discuss this latter finding next time to possibly bring it forward to the NAC.

Dr. McSween noted one science highlight, the special anniversary celebration for the Antarctic meteorite collection or the Antarctic Search for Meteorites (ANSMET), describing it as NASA's "cheapest mission."

Dr. McComas indicated the Science Committee should refrain from commenting on what should be an Agency priority with regard to the PSS NEO survey finding. The question that the SC was qualified to answer was the importance of the scientific goals of the NEO mission. Dr. Green noted that it is important to know that the NEO effort is an authorization, not an appropriation; no money has yet materialized to support the mandate. Dr. McComas recommended that PSD go back to the Decadal Survey process and prioritize the mission accordingly. Dr. Lindberg worried about advocating for a spacecraft-based solution for finding NEOs. The Committee could emphasize instead that the science is important to complete rather than the mission is important to fly. Dr. McComas reiterated that the science perspective was the purview of the Science Committee, and recommended putting the issue on the list for discussion in a joint meeting with HEOC, for a potential joint recommendation that could address the broader issue. Dr. Pieters suggested describing the NEO task as a cross-Agency, cross-division "objective." Dr. Lindberg recommended language that points to the need for a larger collaborative program to carry out the 2005 authorization. Ms. Denning read language from a similar April, 2013 NAC recommendation on an augmented search for small asteroids.

JWST Update

Dr. Eric Smith presented a status of the JWST mission, which is now heavily into the manufacturing and integration and testing (I&T) phase. In response to its annual Government Accountability Office (GAO) examination, the mission fulfilled two recommendations by performing a cost-risk study on adequate reserves, and by providing an updated performance evaluation plan. The year 2015 is the year of assembling the mirror. The funded schedule reserve is currently one month more than that planned for at this stage in development. The Integrated Science Instrument Module (ISIM) has undergone its second major cryovacuum test this year. Near-IR detectors were replaced in the fine guidance system (FGS) and Near Infrared Spectrograph (NIRSpec). The Near-IR Camera (NIRCam) sensor chip assembly (SCA) and SCA light-mask interaction issues have been re-worked. Problems with heat straps (heat pipes that transfer heat out of ISIM) were traced to bolts that were found to be loose. The heat straps have been redesigned and will be replaced. ISIM testing will soon undergo cryovacuum test #3 for about 115 days at GSFC. The backplane will be shipped to GSFC in August, after which mirrors will be placed on it. Other telescope issues include harnesses that are showing nicks. The project is working on how best to remanufacture the harnesses to remain on schedule. JSC is scheduled to start testing the pathfinder telescope to prepare for full-scale testing; the first test is scheduled for May.

The observatory development is proceeding well and has 99% (by mass) of its components in fabrication or already built. A full-scale engineering deployment testing of the sunshield has been successfully completed. Flight sunshield manufacturing is now under way. The aft Unitized Pallet Structure is complete, and the forward part is in progress.

Cryocoolers are complex and remain an issue, because cooler components are distributed throughout the

entire vehicle. The cryocooler has been the most difficult item to manufacture. Each stage is taking longer than forecast, while the measured cooling performance for each stage is as expected. All technical performance metrics are being met. Current watch list items are: the cryocooler, harness issue with the Optical Telescope Element, actuator issues, and electronics for the microshutter. There are 7 of 11 deferred FY 2014 milestones on cryocooler components on the list of milestones that NASA reports to Washington, DC stakeholders.

Addressing JWST's exclusive use period, Dr. Smith noted that NASA wants to maximize science data, while accommodating JWST as a life-limited mission (5-year prime mission, 10-year consumables limit). Like HST, JWST will select a pool of Guest Observers (GOs) on an annual basis. In July 2014, the Space Telescope Science Institute director took the recommendation of the JWST Space Telescope Advisory Committee (JSTAC), and recommended that the GO exclusive user period for new data be 6 months (the current figure is 12 months), as the length of these periods can dramatically affect the amount of data available to proposers in subsequent cycles. So far the U.S. community approves, and NASA is now working with international partners to further shape the agreement. Guaranteed Time Observers (GTOs) will retain their 12-month period. The first GO call for proposals is November 2107; the community needs to learn how to use the software to propose. The first of the annual workshops on "how-tos" is coming up in May, and ESA will be hosting a meeting in October.

Dr. Smith summarized by mentioning the challenges in the I&T period, with reserves continuing to be tight in FY15. Thus far the mission is meeting the challenge to keep the cryocooler on schedule, holding bimonthly telecons and continuing to execute to its launch readiness date (LRD) commitments within the budget.

Lunch Presentation on New Scientific Results from Van Allen Probes and LRO

Dr. Harlan Spence presented a lunch talk on the subject of the Van Allen belts and the charging of the lunar regolith.

Astrophysics FY16 Budget and Division Update/WFIRST/Astrophysics Subcommittee Report

Dr. Paul Hertz gave a status of APD and presented science highlights. HST observed a supernova lensed by a cluster of galaxies, yielding four images. Current models of dark matter predict the emergence of a 6th image 5 or 6 years from now, which could confirm the model for dark matter distribution. Chandra detected a record-breaking outburst from Milky Way's black hole. HST detected distortion of a circumstellar disk by a planet around the star, Beta Pictoris. The Nuclear Spectroscopic Telescope Array (NuSTAR) provided high spatial resolution of high-energy x-rays from the Sun. SOFIA found a link between supernovae and planet formation; more dust is surviving than previously thought, implying that planets could have formed earlier in the universe's history than previously thought. Kepler marked the 1000th confirmation of a Kepler exoplanet discovery, uncovering more small worlds in habitable zones. The International Astrophysical Union (IAU) will be naming some exoplanets this summer. An ultra-long duration balloon flight demonstration, using a super pressure balloon launched from Waneka, NZ, has proven able to maintain a constant altitude through the diurnal cycle. This will allow long-duration balloon flights at mid-latitudes. The balloon has met all technical criteria and has been aloft for 10 days. The eventual goal is to demonstrate 50-100 days (as opposed to 2 days currently), and see if it can be

brought down over land. The next flight will carry a science payload.

APD released its 2014 Implementation Plan in December 2014 and has a number of missions in progress. HST's 25th anniversary will be marked by many events this year, including symposia, exhibits at the Smithsonian Udvar-Hazy museum, and HST day at DC's Nationals Park. The FY15 appropriation and FY16 budget request fully funds JWST and contains funds to continue operating SOFIA, which will enter the Senior Review process in 2016. As of May 2014, SOFIA is in prime operations. APS is also maintaining the cadence of the Explorer program, supporting 4 AOs per decade, alternating small and medium-sized missions. The FY15 appropriation contained an additional $36M (for a total of $50M) directed funding for WFIRST. The FY16 President's budget request remains at about $1.3B for astrophysics (including JWST), supporting all operating missions, funding Explorers, maintaining the balloon program, supporting the commitment to JWST, growing R&A to $90M/year, supporting full funding for SOFIA, and HST operations through 2020. Within the constrained budget, APD has been able to address Decadal Survey science priorities. $100M has been spent over the last 2 years on WFIRST trade studies and technology development; the intent is to be at TRL-5 by KDP-A. The current best estimate for WFIRST, with a coronagraph, in FY10 dollars, is $1.8B, including the launch vehicle, I&T, and operations. In real year dollars, the cost without coronagraph is $2-2.5B, if the mission is started soon. APD is participating with ESA in the L3 gravitational wave observatory and L2 Athena x-ray observatory missions, and is also investing in balloon-borne investigations supporting Inflation Probe science. Funding for the astrophysics ROSES program has been grown to $80M. Proposal numbers have doubled and selection rates have dropped. APD is preparing for the 2020 Decadal Survey, and is requesting well-studied mission concepts that include science case, strawman design, cost box, and technology needs. APD plans to initiate 3-4 concepts studies in 2016 and has provided a starter list to the community for feedback.

WFIRST Update

Dr. Neil Gehrels (online), WFIRST study scientist, provided an update on WFIRST, which has been going well in its pre-formulation phase. The Science Definition Team (SDT) report is complete, and design work and technology development is ongoing. An NRA will be issued soon to select a science team. The SDT team included international participants, as Canada and Japan are interested in participating at some level. WFIRST is designed to make significant progress in collecting data about dark energy and exoplanets, covering about 100 times more sky than HST. A coronagraph is now considered a baseline element for the mission. A level of 10^{-9} contrast will be reached for the first time by the WFIRST coronagraph, enabling the characterization of planets around nearby stars. Now is the right time to use funding for WFIRST to reduce the risk in developing detectors and the coronagraph. WFIRST will carry out a supernova survey to study dark energy and employ microlensing techniques to study exoplanets. While Kepler detects planets near stars, the WFIRST microlensing survey will detect planets far from their stars, as well as hundreds of free-floating planets. WFIRST advances many key elements needed for a coronagraph to image an exoEarth. A quarter of the prime mission will be devoted to GOs. The WFIRST High Latitude Survey is expected to increase detection of high redshift galaxies by 2 orders of magnitude. The current long wavelength cutoff is 2 microns at the current temperature range, but 2.4 microns may still be possible. Asked if weak lensing would be compromised by a heavily obscured telescope, Dr. Gehrels replied that the team is studying this; there is some degradation in weak lensing,

compensated for by a much larger collecting area. Dr. Gaudi added that the survey strategy had been changed somewhat to control systematics; a deeper rather than wider approach.

Astrophysics Subcommittee Report

Incoming APS Chair Dr. Scott Gaudi reported on the activities of a partly reconstituted APS. At its latest meeting, the subcommittee heard updates from JWST, the balloon program, and the NICER team. The APS concurred (with one negative vote) with the JWST Advisory Committee (JSTAC) recommendation that the JWST GO program limited access period be shortened to 6 months. The subcommittee also heard an interim report from the Astronomy and Astrophysics Advisory Committee (AAAC) Proposal Pressures Study that addressed decreasing selection rates in the Astrophysics R&A program (APRA), and that found no single clear cause thus far. A final report is in progress. A near-final report from the Planck mission indicated that the mission's data set represents a gold standard for many decades to come. APS also heard final reports from the Exo-C and Exo-S (exoplanet) probe class studies. The Exo-S final report focused on starshade architecture, a 1m telescope without wavefront correction, and found that the telescope could resolve planets very close to their stars by using of a starshade. The report also looked at a rendezvous mission with WFIRST. Exo-S science goals are to directly image planets and obtain their spectra. Exo-S is envisioned as a stand-alone mission that will image a few thousand planets and characterize a few spectra. A rendezvous mission with both Exo-S and WFIRST would get slightly more spectrally resolved planets at a cost of $600M. Exo-C is a single telescope with starlight suppression inside the telescope via optics and other advanced techniques; this mission would resolve a couple dozen planets to characterize by spectra, at a cost of slightly more than $1B, using some heritage from Kepler.

Dr. Gaudi noted that APD has given a charge to the community on concept studies of several reference missions: a far-IR surveyor with 6-10m mirrors; a large ultraviolet/optical/IR (LUVOIR) telescope with an 8-16m, likely segmented mirror; an X-ray Surveyor; and a Habitable Exoplanet Finder, with a 4-8m monolithic mirror, (10^{-10} contrast, coronagraph). The Exoplanet Exploration Program Analysis Group (ExoPAG) plans to respond to the large mission charge and already has held a joint PAG Executive Meeting; the community can provide input at various meetings and virtual Town Halls.

Public Comment

Dr. Richard Binzel, an asteroid scientist at MIT, suggested asking the NAC to evaluate synergies across the Agency for supporting a space-based NEO survey. The NAC could send this back to the Science Committee for consideration but that would be fine.

Discussion, Findings and Recommendations

The Committee wrapped up discussion of findings and recommendations to bring to the NAC that included:

- Long-term retention of samples (Recommendation)
- Approval of contractor participation in conferences (Recommendation)
- Space radiation (Joint HEOC/SC recommendation)
- Collaboration (Joint HEOC/SC finding)

Items that did not go forward at this meeting included:

- A PSS finding on international collaboration was tabled for the interim.
- An HPS finding on the matter of a new HPD program director did not go forward. Dr. McComas suggested that Dr. Grunsfeld's assurances against absorbing HPD into another division seem to be adequate.

Ms. Denning thanked Dr. McComas for his leadership of the Science Committee. Dr. McComas took final comments from around the table for future topics. Dr. Robinson suggested engineering aspects of radiation shielding. Dr. Lindberg suggested hearing more about methane observations and frost data from Curiosity, as well as holding a joint PSS/PPS meeting. Dr. McComas adjourned the meeting at 4:34 pm.

Appendix A
Attendees

NAC Science Committee Members
David J. McComas, Southwest Research Institute, *Chair,* Science Committee
Scott Gaudi, Ohio State University, Chair, Astrophysics Subcommittee
James Green, University of Colorado at Boulder
Maura Hagan, NCAR, Chair, Heliophysics Subcommittee
Robert Kirshner, Harvard University
Janet Luhmann, UC Berkeley, Chair, Planetary Science Subcommittee *(via telecom)*
Robert Lindberg, Jr., University of Virginia, Chair, Planetary Protection Subcommittee
Harry McSween, University of Tennessee *(designee)*
Carlé Pieters, Brown University
Mark Robinson, Arizona State University
Steve Running, University of Montana, Chair, Earth Science Subcommittee
Harlan Spence, University of New Hampshire
David Spergel, Princeton University, *ex officio*
Elaine Denning, NASA Headquarters, *Executive Secretary*

NASA Attendees
Gabriel Adler, NASA Headquarters
Gale Allen, NASA Headquarters
Marc Allen, NASA Headquarters
Therese Arrivo, NASA Headquarters
Lora Bailey, NASA Headquarters
Max Bernstein, NASA Headquarters
Steve Blattnig, NASA Headquarters
Steve Clark, NASA Headquarters
Steve Cole, NASA Headquarters
Catharine Conley, NASA Headquarters
Jeffrey Davis, NASA Headquarters
Steve Davison, NASA Headquarters
Michael Freilich, NASA Headquarters
Teresa Fryberger, NASA Headquarters
William Gerstenmaier, NASA Headquarters
James Green, NASA Headquarters
John Grunsfeld, NASA Headquarters
Lika Guhathakurti, NASA Headquarters
Hashima Hasan, NASA Headquarters
Jeffrey Hayes, NASA Headquarters
Tyler Hesford, NASA Headquarters
Paul Hertz, NASA Headquarters
Lou Kaluzienski, NASA Headquarters
Jana Killebrew, NASA Headquarters
Robert Leamon, NASA Headquarters
Jared Leisner, NASA Headquarters
Ruthan Lewis, NASA GSFC
David Liskowsky, NASA Headquarters
Andrea Martin, NASA Headquarters
Robin Mauk, NASA GSFC

Joseph McIntyre, NASA Headquarters
Michael Meyer, NASA Headquarters
Walter Miller, NASA Headquarters
Jeff Morrill, NASA Headquarters
Jeff Newmark, NASA Headquarters
John Norbury, NASA Headquarters
Anne Marie Novo-Gradai, NASA Headquarters
William Paloski, NASA Headquarters
Bill Paterson, NASA Headquarters
Jonathan Pellish, NASA Headquarters
Arik Posner, NASA Headquarters
Betsy Pugel, NASA Headquarters
Diane Rausch, NASA Headquarters
Christy Rivera, NASA Headquarters
Shawanda Robinson, NASA Headquarters
Jenny Rumburg, NASA Headquarters
Victor Schneider, NASA Headquarters
Lisa Simonsen, NASA LaRC
Tony Slaba, NASA Headquarters
Eric Smith, NASA Headquarters
Erin Smith, NASA Headquarters
Myra Sambacus, NASA GSFC
Rita Sambruna, NASA Headquarters
O. C. St. Cyr, NASA GSFC
Ed Semones, NASA JSC
Jeremy Stembler, NASA Headquarters
Ellen Stofan, NASA Headquarters
ElSayed Talahi, NASA Headquarters
Ray Taylor, NASA Headquarters
Lucia Tsaoussi, NASA Headquarters
Craig Tupper, NASA Headquarters
Allan Tylka, GSFC
Dan Woods, NASA Headquarters

Human Exploration and Operations (HEOC) Members
Mr. Ken Bowersox, Former NASA astronaut and retired U.S. Navy Captain, *Chair*, HEO Committee
Ms. Shannon Bartell, Former director of Safety and Mission Assurance at NASA's Kennedy Space Center
Dr. Leroy Chiao, Former NASA astronaut and International Space Station Commander
Dr. Stephen "Pat" Condon, Aerospace Consultant
Mr. Tommy Holloway, Former Space Shuttle and International Space Station Program Manager
Mr. Lon Levin, SkySevenVentures
Dr. David E. Longnecker, National Academy of Sciences Institute of Medicine (IOM)
Mr. Michael Lopez-Alegria, Commercial Spaceflight Federation
Mr. Bob Sieck, Former Space Shuttle Launch Director.
Mr. James Voss, University of Colorado, Boulder
Dr. Bette Siegel, NASA Headquarters, *Executive Secretary*

Non-NASA Attendees
Susan Avery, Woods Hole Oceanographic Institution
Veronica Bindi, University of Hawaii

Francesco Bordi, Aerospace
Joe Gillin
Brad Keelor, British Embassy
Larry Nittler, Carnegie Institute of Washington
Nathan Schwadron, University of New Hampshire
Ana Wilson, Zantech IT
Joan Zimmermann, Zantech IT

Telecon and Webex Attendees
Natalia Alexandrov, NASA Langley Research Center
Louis Barbier, NASA HQ
Karl Becker, NASA HEO
Richard Binzel, MIT
Stacey Boland, JPL
Darrell Branscome, DRB Associates Corp
Elizabeth Buchen, SpaceWorks
Paul Campbell, Lockheed Martin
Lisa Carnell, NASA
Brad Carpenter, NASA
Mark Carreau, Aviation Week and Space Technology
Mike Ching, NASA
Stephen Clark, Space Flight Now
Martha Clowdsley, LaRC
Al Condes, NASA
Anne Connor, Exelis
Keith Cowing, Private Citizen
Michael Crandall, Boeing
Nicholas Cummings, US Senate
Monty DiBiasi, Southwest Research Institute
Cynthia Dinwiddie, Southwest Research Institute
Marylynne Dittmar, Dittmar Associates
Bret Drake, NASA JSC
Therese Errigo, GSFC
Jeff Fous, Space News
Nathan Gaya
Neil Gehrels, NASA GSFC
David Herlock, OSTP
David Hermreck, OSTP
Showen Hu, Johnson Space Center
Janice Huff, USRA
Richard Irving, NASA
Brad Johnson, Goddard
Andrew Jordan, University of NH
Jason Kalirai, Space Telescope
Dan Kane
Jennifer Kearns, NASA Headquarters
Yared Kidane, Wyle
Myung-Hee Kim, NASA JSC
Irene Klotz, Reuters
Theodore Kronmiller, Law Office Theodore Kronmiller

Michael Lembeck, Logyx
Dan Leone, SpaceNews
Mario Livio, Space Telescope Science
Sashka Mannion, NASA OIG
Brian Mayeaux, JSC
Kevin Miller, Strategic Space Solutions
David Millman, N/A
Mike Mineiro, Independent
Michael Moloney, National Research Council
Sherry Monk, NASA Langley
Frank Morring, Aviation Week
Ryan Norman, Langley Research
Richard Passmore
Daniel Peters, NY Skies
Ianik Plante, Johnson Space Center
Jeff Plescia, Johns Hopkins University
Mark Postman, SpaceTelescope Science Institute
Julie Rathbun, Monetary Science Institute PSI
Duane Ratliss, Contineo
Kurt Retherford, Southwest Region Institute
Christian Rice, House Committee on Science
Richard Rogers, Stellar Solutions
John Rummel, East Carolina University
Tara Ruttley, NASA
Stephanie Schierholz, NASA
Mitch Schulte, NASA HQ
Zarana Shavers, NASA
Gerald Smith, NASA Headquarters
Marcia Smith, Spacepolicyonline.com
Massimo Spiabelli, Space Telescope Science Institute
Jared Stout, US State House of Rep
Rhonda Stroud
Amy Svitak, Aviation Magazine
George Tahu, NASA Headquarters
Craig Tally
Kim Terrell, Katz International Management Solutions
AndrewThomas, NASA
Raymond Tolomeo, NASA
John Uri, JSC Human Research Program
Gayathri Vaidyamthan, Climatewire
Roeland Van Der Marel, Space Telescope Science Institute
Charles Werneth, NASA Langley
Angela Williams, Zantech IT
Jody Wilson, University of NH

Appendix B
NAC Science Committee Membership

Dr. David J. McComas, Chair
Southwest Research Institute

Dr. Douglas Duncan
University of Colorado at Boulder

Dr. Maura Hagan
National Center for Atmospheric Research

Dr. B. Scott Gaudi
Ohio State University

Dr. James C. Green
University of Colorado

Dr. Robert P. Kirshner
Harvard University

Dr. Robert E. Lindberg, Jr.
University of Virginia

Dr. Janet Luhmann
University of California, Berkeley

Dr. Carlé Pieters
Brown University

Dr. Mark S. Robinson
Arizona State University

Dr. Steven W. Running
University of Montana

Dr. Harlan E. Spence
University of New Hampshire

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

Ms. Elaine Denning, Executive Secretary
NASA Headquarters

Appendix C
Presentations

1. MESSENGER at Mercury: Scientific Highlights and End of Mission; *Larry Nittler*
2. Planetary Protection Report to the Science Committee; *Robert Lindberg*
3. FY 2016 Budget Overview to the NAC Science Committee; *Craig Tupper*
4. Earth Science Division FY16 President's Budget Request Overview and Program Status; *Michael Freilich*
5. Joint Agency Satellite Division NAC Science Committee Update; *Steve Clarke*
6. Heliophysics Division Overview; *Jeff Newmark,*
7. Heliophysics Subcommittee Report; *Maura Hagan*
8. Space Radiation Presentation Outline
9. Mars Mission and Space Radiation Risks Overview; *Steve Davison*
10. Institute of Medicine Report and Office of the Chief Health and Medical Officer Implementation Plan; *David Liskowsky*
11. Space Radiation Environment; *O.C. St. Cyr*
12. The Solar Energetic Particle Radiation Hazard; *Allan Tylka*
13. Space Radiation Environment Comparison and Validation of GCR Models; *Tony Slaba*
14. Implications of the Worsening GCR Radiation Environment; *Nathan Schwadron*
15. Emerging GCR Data from AMS-2; *Veronica Bindi*
16. Radiation Health Risk Projections; *Edward Semones*
17. Mars Mission and Space Radiation Risks; *Lisa Simonsen*
18. Planetary Science Division Report; *James Green*
19. Planetary Science Subcommitttee Report to NAC Science Committee; *Harry McSween*
20. James Webb Space Telescope Update; *Eric Smith*
21. Truths and Consequences of Ionizing Radiation: New Science Results from Van Allen Probes and LRO; *Harlan Spence*
22. Astrophysics Division Update; *Paul Hertz*
23. WFIRST-AFTA Update; *Neil Gehrels*
24. Astrophysics Subcommittee Meeting Summary Report; *Scott Gaudi*

Appendix D
Agenda

NASA Advisory Council
Science Committee

Meeting
April 6-8, 2015
NASA Headquarters
Room 3H42

Agenda

Science Committee Meeting

Monday, April 6

1:00 - 1:15	Opening Remarks / Introduction of Members	Ms. Elaine Denning Dr. David McComas
1:15 - 2:00	MESSENGER End of Mission	Dr. Larry Nittler
2:00 - 2:15	Planetary Protection Subcommittee Report	Dr. Robert Lindberg
2:15 - 2:45	Overall NASA and SMD FY16 Budget	Mr. Craig Tupper
2:45 - 3:00	***BREAK***	
3:00 - 4:00	FY16 Budget and Division Update ESD Earth Science Subcommittee Report	Dr. Michael Freilich Dr. Steve Running
4:00 - 5:00	Discussion / Potential Findings and Recommendations	
5:00	***ADJOURN***	

Tuesday, April 7

8:00 - 8:05	Re-convene Meeting	Ms. Denning Dr. McComas
8:05 - 9:00	JASD Update	Mr. Steve Clarke
9:00 – 9:55	FY16 Budget and Division Update HPD Heliophysics Subcommittee Report	Dr. Jeff Newmark Dr. Maura Hagan
9:55 - 10:05	***BREAK***	
10:05 – 10:30	Travel Discussion	Mr. Joseph McIntyre

10:30 - 11:30	Discussion with SMD Associate Administrator	Dr. John M. Grunsfeld
11:30 - 12:00	Discussion / Potential Findings and Recommendations	
12:00	***LUNCH***	

Science Committee / Human Exploration and Operations Committee Joint Meeting

1:00 - 1:02	Call to Order & Welcome	Dr. Bette Siegel & Ms. Denning
1:02 - 1:10	Opening Remarks & Member Introductions	Mr. Kenneth Bowersox Dr. McComas
1:10 - 3:00	Space Radiation and Discussion	Dr. Steve Davison, Dr. Chris St. Cyr, Dr. Allan Tylka, Dr. Tony Slaba, Dr. Nathan Schwadron, Dr. Veronica Bindi, Dr. Eddie Semones, Dr. Lisa Simonsen, Dr. David Liskowsky
3:00 - 3:15	***BREAK***	
3:15 - 5:15	Space Radiation and Discussion	
5:15 - 5:20	Public Comments	
5:20 - 5:30	Wrap Up	
5:30	***ADJOURN***	

<u>Wednesday, April 8</u>

8:30 - 8:32	Call to Order, Welcome & Opening Remarks	Mr. Bowersox & Dr. McComas Dr. Siegel & Ms. Denning
8:32 - 10:00	Joint HEOC/SC Discussion	
10:00	***ADJOURN JOINT MEETING***	

Science Committee Meeting

10:00 - 10:15	***BREAK***	
10:15 - 11:30	FY16 Budget and Division Update PSD Planetary Science Subcommittee Report	Dr. James Green Dr. Harry McSween
11:30 - 12:15	JWST Update	Dr. Eric Smith
12:15 - 1:15	***LUNCH*** – Member Research Presentation "Truths and Consequences of Ionizing Radiation: New Science Results from Van Allen Probes and LRO"	Dr. Harlan Spence
1:15 - 2:45	FY16 Budget and Division Update APD WFIRST Update Astrophysics Subcommittee Report	Dr. Paul Hertz Dr. Neil Gehrels Dr. Scott Gaudi
2:45 - 3:00	***BREAK***	
3:00 - 3:05	Public Comment	
3:05 - 5:00	Discussion, Findings and Recommendations	
5:00	***ADJOURN***	

Dial-In and WebEx Information

For entire meeting April 6-April 8, 2014

Dial-In (audio): Dial the USA toll-free conference call number (800) 988-9663 or toll number (517) 308-9483 and then enter the numeric participant passcode: 8015. 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 999 655 441, and the password is Science@Apr2015.

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