

NASA ADVISORY COUNCIL

SCIENCE COMMITTEE

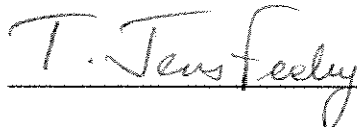
April 20-21, 2010

NASA Goddard Space Flight Center
Greenbelt, MD

MEETING MINUTES



Wesley T. Huntress, Chair



T. Jens Feeley, Executive Secretary

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Welcome and Introduction

Dr. Wesley T. Huntress, Chair of the NASA Advisory Council (NAC) Science Committee, opened the proceedings, thanking the director of the Goddard Space Flight Center (GSFC) for hosting the meeting. T. Jens Feeley, Executive Secretary made some brief logistical announcements.

Dr. Huntress alluded to President Obama's April 15, 2010, visit to the Kennedy Center, welcomed the new NASA funding contained in the FY11 budget request, as well as a clear plan with timeframes for destinations. He briefly reviewed three recommendations that had been transmitted to NASA Administrator Charles Bolden, namely strong NAC Science Committee support for the development of a new technology program, a proposed re-initiation of Pu-238 production in the U.S., and the establishment of various new NAC Science Subcommittee analysis groups.

Goddard Space Flight Center (GSFC) Welcome

Dr. Rob Strain, Director of Goddard Space Flight Center, briefly addressed committee members, noting that GSFC had celebrated its 50th anniversary in 2009, which had been one of the center's busiest years in launch schedules. In 2010 thus far, GSFC has supported the successful launch of the Solar Dynamic Observatory (SDO) and the latest Geostationary Operational Environmental Satellite, GOES-P. The center is currently in the midst of a hiring campaign to bring in younger staff, addressing the demographic challenge of a rapidly retiring science and engineering community. Fifty percent or more hires for GSFC are slated to be fresh-outs (terminal degree plus 3 years).

GSFC has supported over 300 Earth and Space system missions in its history. GSFC also oversees the Wallops Island suborbital launch facility in Virginia, the Independent Verification & Validation Facility in West Virginia, ground stations at White Sands, and the Goddard Institute for Space Science (GISS) in New York. At present, the center employs approximately 3200 civil servants and over 5400 contractors on site; two-thirds of this population is comprised of scientists and engineers. Mr. Strain introduced GSFC senior staff, Dr. Orlando Figueroa, Deputy Director for Science and Technology, and Dr. Nick White, Director of the Sciences and Exploration Directorate.

GSFC is addressing three major initiatives: the James Webb Space Telescope (JWST), which completed a mission critical design review (CDR) the previous week. The center is also in the process of standing up an office to support NASA Headquarters (HQ) in the newly formulated Joint Polar Satellite System (JPSS) program, formerly known as NPOESS. GSFC is also engaged in mission collaborations with academia and other centers such as Langley Research Center (Climate Absolute Radiance and Refractivity Observatory; CLARREO), Ames Research Center (Lunar Atmosphere and Dust Environment Explorer; LADEE), and the Jet Propulsion Laboratory (Mars Science Lander; MSL). The center is providing a critical instrument for MSL, a laboratory suite called Sample Analysis at Mars (SAM). Asked if the center suffered any restrictions on collaborating with universities, Mr. Strain responded that there were none that he is aware of. GSFC is free to join, lead, or support science teams at other institutions and attempts to be responsive to a variety of scientific initiatives. Dr. Ed Weiler, Associate Administrator of the NASA Science Mission Directorate (SMD) clarified the term "support" in this context to signify manpower, laboratory usage, etc., and not funding.

Dr. Judith Lean asked about the status of full-cost accounting (FCA) at NASA. Mr. Strain noted that NASA has proposed to resume its unified labor practices and has done some planning to be ready to implement this practice. The earliest implementation of such a change, pending approval, would be FY11. Dr. Weiler felt there was a 70-80% likelihood that this would occur, and commented on the amount of management time spent addressing Center staffing levels (specifically Available for New Work or AFNW reviews) in recent years.. Dr. Byron Tapley asked if there were any obstacles to a zero-funded contract

that would allow the transfer of funds between institutions. Dr. Weiler felt that most contracts were already covered by the Space Act. Other possible collaborations could take the form of staff-sharing, student mentoring, work on joint research and development (R&D) activities, leveraging of activities, office space, and even parking.

Dr. Figueroa continued the presentation, noting GSFC's contribution to NASA's diverse mission portfolio, and particularly its contribution to the 2006 Nobel Prize in Physics that was awarded to NASA's Dr. John Mather. GSFC has significant capability throughout SMD, in all of its four disciplines of Astrophysics, Heliophysics, Earth Sciences, and Planetary Sciences. In the last few years, an unprecedented amount of work has passed through the center, including the Fermi Gamma-Ray Space telescope (formerly GLAST), the National Oceanic and Atmospheric Administration (NOAA) N-Prime mission, the Orbiting Carbon Observatory (OCO), the Lunar Reconnaissance Orbiter (LRO), and as previously mentioned, SDO. The Glory mission will be launched in November 2010. In the near-term, GSFC will be supporting the LADEE mission to the Moon, ICESat II, NPP (a preparatory mission for JPSS), Glory-Magnetospheric Multiscale (MMS), the Gravity and Extreme Magnetism Small Explorer (GEMS), the LandSat Data Continuity Mission (LDCM), next-generation Tracking and Data Relay Satellite System (TDRSS), the delivery of the SAM instrument to MSL, the Mars Atmosphere and Volatile Evolution (MAVEN) mission, and the Joint Dark Energy Mission (JDEM) mission definition activities. The last two years have presented some challenges, but GSFC has been successful in winning new missions, providing instruments and supporting other mission activities. The center views itself as a steward and enabler for the entire scientific community. Dr. Huntress commented on the growing trend of Planetary activity at GSFC and asked if there was a conscious strategy to carve a niche in Planetary missions. Dr. White responded that the center was indeed building on natural extension to Planetary science through open competition, and its successful history in Planetary missions. Dr. Huntress noted that entry probes might be a good area of concentration for the center.

Dr. Lean asked if GSFC would absorb any commitments to JPSS. Dr. Figueroa explained that the leadership for JPSS resides in NOAA, and that NASA would function as an implementer, also providing research, instruments, data analysis, and validation/calibration activities in supporting the NOAA effort. Asked when a long-term plan would emerge, Dr. Figueroa responded that NASA is in the process of helping to define the way forward and determining the roles of instruments- the focus until recently has been on establishing the JPSS program office and minimizing downtime between launches. Mr. Strain added that NASA is also trying to help NOAA mitigate data gaps as the mission has begun to divide its time between day and night orbits. It is not yet known what the Department of Defense (DoD) plans to do in its share of the mission. NOAA also lacks funding until FY11. Dr. Tapley observed that while there is a great deal of relief in the mode of implementation, the essential requirements are still unclear. Dr. Figueroa conceded that competing requirements have been a challenge; to this end, NASA has been working on strengthening scientific capabilities and relevant instruments for the morning orbit; this is still in the formative stages. In addition, the Agency has been diligently working to keep NASA's Earth Sciences Division and JPSS separate. Data stewardship is being sorted out instrument by instrument, and data set by data set.

Dr. Figueroa reported that the center is working hard to deliver the very complex JWST, methodically addressing all the challenges, and looking toward a successful launch in 2014. Dr. Burns asked if thought were being given to potential service missions to JWST. Dr. Huntress and Dr. Weiler agreed that JWST was not intended to be serviced, given its distant orbit at Lagrange Point 2. Dr. Weiler added that such servicing would be too costly, noting that the total Hubble Space Telescope (HST) cost, has been roughly \$18B, a substantial portion of which is attributable to its servicing-related costs (including Shuttle launches and related manpower).

Dr. Figueroa enumerated other challenges to JWST, namely verification and validation, as the telescope cannot be tested end-to-end on the ground. Thermal stability and the operating environment for the instruments present a significant challenge to the project, and create stress on the programmatic level as well. The Ariane V load measurement have been fluctuating, leading to frequent re-analysis, and pushing the capabilities of centers and partners. In answer to a question on the rationale for JWST's placement at the Sun Earth L2 point, it was explained that Earth's infrared signature was too bright at closer orbits; JWST can also observe the sky 100% of the time, unocculted by Earth, in a benign thermal environment. Dr. Weiler also expressed great confidence in Dr. Figueroa and Dr. Gene Oliver as historically successful engineers.

Within GSFC Heliophysics, SDO, which endured a waiting period of more than a year, is already gathering good science data after its February 2010 launch. SDO's minimum lifetime threshold is 3 years. Dr. Weiler felt there was no reason SDO would not last longer than 3-5 years, given the history of NASA engineering; SOHO, for example, has been in operation since 1996. Thus far SDO has had no technical issues. Dr. Weiler disapproved of the misinformation about SDO's cost growth. Dr. Figueroa agreed, noting that SDO was in fact delivered within 1 or 2% of the intended cost, if one factors out the cost of launch delays and programmatic irregularities.

GSFC Earth Sciences is focusing on the Global Precipitation Measurement (GPM) mission, and is also supporting the ICESat 2 mission. In its support of Planetary Sciences, the center is highly focused on delivering SAM to the MSL. SAM will be the most sophisticated instrument suite ever to land on another planet, and will make unprecedented biochemical measurements *in situ*. Engineers are currently struggling with a high-rpm pump, which is scheduled for delivery in December 2010; Dr. Figueroa expected the problem to be solved on schedule. Dr. Burns asked how GSFC was planning to support Exploration. Dr. Figueroa replied that GSFC was supporting four Exploration Systems Mission Directorate (ESMD) teams on robotic scouts, robotic precursors, flagship technology demonstrations, and at Wallops Island, viewing these efforts as preparatory science for addressing exploration-specific questions. Dr. Weiler interjected that robotic precursors are not science missions, and thus not a purview of SMD. LRO and LADEE are also not science-driven missions. He added that SMD would not be funding ESMD activities, the International Space Station (ISS), or other non-scientific programs within NASA. Dr. Figueroa explained that in lieu of funds, GSFC provides support to ESMD teams by offering GSFC strengths in avionics, extravehicular activity (EVA) tools, and instruments to support human exploration, focusing on science through competition. Dr. Weiler added that this is a sensitive issue regarding programs and missions, and that HQ ultimately decides which centers get missions. Mr. Strain noted that rather than building capabilities for Exploration, GSFC would participate where it was deemed fitting. Dr. Eugene Levy asked for clarification in how NASA decides what new capabilities are needed. Mr. Strain explained by way of example that GSFC would not lead a flagship mission, but would stick to its niche, and assessing individual cases. Dr. Levy suggested, given the ambitions of the space program to expand the envelope, that NASA inventory its capabilities and decide which ones to sustain and build.

Dr. Huntress took an action to invite Mr. Doug Cooke to the next Science Committee meeting to crystallize the concept of Exploration science. Dr. Burns suggested inviting Dr. Laurie Leshin as well. Dr. Weiler noted that the ESMD was considering developing a lander for *in situ* resource utilization (ISRU), and that science could benefit from a radio frequency and optical communications relay on a satellite in conjunction with the lander. Dr. Weiler stated that it was his preference that science participation in ESMD missions would be decided through the Missions of Opportunity (MOOs) competition in the Discovery, New Frontiers and Explorers programs. ESMD missions must be well defined in order to determine what science's role will be. However, SMD is already involved in precursor mission planning, with critical senior staff, serving on ESMD-led teams to define future missions.

Dr. Huntress briefly introduced Dr. Alan Boss as the incoming Chair of the Astrophysics Committee, whose paperwork was in progress at the time of the meeting.

NASA SMD Science Plan

Mr. Greg Williams presented an update on the progress of the 2010 NASA Science Plan, reviewing the schedule as the Plan had gone through successive evaluations by each NAC Science Subcommittee. Feedback has been incorporated and the goal is to publish the Plan by June 2010. Other changes must be incorporated, particularly given the President's address on April 15, 2010 at the Kennedy Space Center. Language has been added, as suggested by the Science Committee, describing a fuller articulation of partnership interfaces and boundaries, a strategy for international partnerships, and an approach to managing cost overruns. The issue of a new technology development plan has been added to the Science Plan's set of challenges, as well as a series of text boxes highlighting cross-disciplinary research. Asked whether the concern over cost overruns had been included in the new language, Mr. Williams explained that this had been addressed by providing resources for early estimations, and a discussion of the impact of the 70% confidence rule (e.g., starting fewer missions). A brief discussion ensued on whether to include details on criteria for cancelling a mission. Dr. Feeley felt that because there are Congressional and Agency limits governing these criteria, the details need not be in the Science Plan. There was general agreement in the Science Committee to the contrary; i.e. that a more detailed description of cancellation criteria be included.

Dr. Burns noted that smaller missions seem to manage costs well, and that the Science Plan should give the Agency adequate credit for this by balancing a statement of cost overruns with a better definition of the problem. Dr. Lean suggested equating increased risk/complexity with increased cost. Dr. Levy commented that NASA exists in part to stretch capacity, such that risk is a virtue if properly understood and managed. Dr. Weiler reminded the Science Committee that NASA's budget request includes a proposed \$1B investment in a new cross-cutting technology development program, which can be used for small, medium and large missions, and which would be managed through the new Office of the Chief Technologist. Dr. Lean recommended distinguishing between unrealized vs. unrealistic expectations. Mr. Williams suggested this be expressed as documenting the difference between expectations and reality.

Also in response to feedback, the Science Plan has revised its science questions and objectives, and has modified a statement on Exploration Science to a text box summarizing how SMD science contributes to Exploration. Mr. Williams noted that SMD is still reacting to uncertainty in Exploration destinations. Dr. Greeley suggested including some acknowledgment of science as guided by the discipline NRC Decadal Surveys. Dr. Huntress felt it would be useful to reiterate how the nation conducts its scientific enterprise, by creating a better statement of SMD's separateness from Exploration, emphasizing that peer review and competition will continue to guide SMD, creating the best science and science missions. Mr. Williams noted that this philosophy is already stated in the Principles section, and asked for specific edits to help strengthen the statement. It was also suggested that the competitive nature of the Decadal Surveys themselves be conveyed.

Mr. Williams reported that the Science Plan now includes a discussion of dissemination of results in open-access journals, modification of some planetary science questions, and the addition of Near-Earth Object (NEO) detection and tracking as mandated by Congress, a table of the current subcommittees, updated challenges to the FY11 budget request, and cost considerations in the Access to Space section. Specific comments from the Science Subcommittees on the Science Chapters have also been incorporated. Dr. Lean noted that the Sun should be better described as the primary source of electromagnetic radiation. A brief discussion ensued on the accuracy of NASA's statement on its unique Earth Sciences integrated research program. Dr. Tapley felt this was a defensible claim, but agreed with other Science Committee members that specific capabilities be listed and verified, in lieu of making a

“rankling” statement.

Mr. Williams reviewed the final steps before publication, and hoped to use the first half of May for review after holding the comment period open until the end of April.

Major science highlights in Earth Science have been incorporated into the Science Plan, including understanding Antarctic “plumbing” and the influence of temperature changes, interactions with aerosols that boost the warming potential of some gases, the decline in Arctic sea ice over time, and detection of groundwater depletion in California and India. Dr. Weiler suggested using a longer data record (back to the 1980s) to show both variation and decline in Arctic sea ice. Dr. Lean suggested mentioning the mandate from Congress to monitor the Earth’s ozone hole, or adding some stratospheric data.

Heliophysics science highlights now include recent observations of magnetic reconnection within the auroras, data on the anatomy of solar coronal mass ejections (CMEs), evidence of the galactic magnetic field shaping the heliosphere from the Interstellar Boundary Explorer (IBEX), and first light data from SDO. Dr. Lean suggested adding data on polar mesospheric clouds, and observation of Shuttle plumes, as well as the current anomalous solar minimum and its effects on the ionosphere/thermosphere/mesosphere.

Planetary science highlights include Cassini’s observations of the plumes on the Saturn satellite, Enceladus, evidence of water on the lunar surface and methane on Mars, and signs of past surface water on Mars. Dr. Weiler suggested adding photos of Mars craters surrounded by ice, and MESSENGER’s first global map of Mercury.

Astrophysics science highlights include the latest HST results, images from the Physics of the Cosmos missions such as Chandra and the Fermi telescope, initial Kepler results on detection of new exoplanets, and detection of methane and carbon dioxide in exoplanetary systems.

Lunch talk

Dr. Compton Tucker presented data on tropical glacier extent variation in the New World, and Dr. Thorston Markus presented recent findings on Arctic sea ice measurements.

Planetary Sciences Subcommittee Update

Dr. Ron Greeley, Chair of the Planetary Sciences Subcommittee (PSS), briefed the Committee on recent activities within PSS, first highlighting the products of its 6 analysis groups. He noted that at the Rayburn Building in Washington, D.C. on July 15, 2010, there will be an exhibit celebrating the 400th anniversary of the discovery of the Galilean satellites; this exhibit will focus on science results from the NASA-ESA Galileo spacecraft, as well as current and future exploration of the Outer Solar System. The European Space Agency (ESA) and NASA have signed a letter of agreement regarding a potential mission to Europa and the Jupiter planetary system (Europa Jupiter System Mission). PSS also put forth a finding supporting the re-initiation of Pu-238 production in the U.S. to support planetary science missions. A finding on the International Mars Program, noting progress towards an international collaboration working toward sample return, was also noted, recognizing the need for the cooperation of science and technology cultures, on both sides of the Atlantic, to reach this goal. Technologists need to understand the science motivation, and scientists need to better appreciate technical limitations.

PSS delivered a finding on uncosted carryover funds. Dr. Greeley observed that Congress seems to recognize that in the case of the National Science Foundation (NSF), for instance, there are legitimate reasons for this carryover, however, to date Congress does not seem to realize that many of these same reasons apply to NASA activities. PSS has therefore recommended that Congress be made aware of the elements at NASA that have similar issues leading to uncosted carryover. Dr. Weiler suggested, as a

means of amelioration, that each university grant officer establish a personal relationship with a contact at NASA to better manage uncosted carryover. A meeting participant commented that a use-or-lose policy could be beneficial in clearing the books. Dr. Weiler added that NASA has tamed the unobligated carryover, but is worried that Congress will next target uncosted carryover. The Science Committee recognized that the community must take pains on educating itself on this issue.

PSS has made a recommendation on a potential collaboration between SMD and ESMD, especially in robotic precursor missions, to formulate a "Humans to Moon, Asteroids and Technology Roadmap" to help guide robotic missions. Such a Roadmap would be beneficial to PSD and ESMD and could use as a basis documents from existing analysis groups.

PSS has also recommended that ESMD and SMD collaborate on the next call at the Lunar Science Institute (LSI) to support and enhance the goals of both directorates. Dr. Weiler reminded the Science Committee (SC) that the LSI was imposed by a different administration; in addition, none of this money for ESMD's new missions has been appropriated and there is no budget for exploration precursors. Dr. Greeley stated that PSS was merely trying to prioritize science through this recommendation, where there is mutual interest. Dr. Weiler felt that the Decadal Survey's South Aitken Basin proposal was the only appropriate project for SMD, since it is the only one that had been competitively peer-reviewed. Dr. Levy commented that where there are accepted science objectives, the community ought to respond with alacrity, but supported Dr. Weiler's objections; he felt that the lunar objective had distorted the science issue, and that the SC's role was to reframe priorities in a rational fashion.

PSS has recommended that the Lunar Exploration Roadmap (LER) be used to guide relevant science issues, and sought guidance from the Science Committee on what PSS should do next in the context of LER. Dr. Huntress felt that by the Summer/early Fall, there would probably be some clarification of exploration plans, and requested that Dr. Greeley hold the recommendation on LER until the next meeting.

PSD Science Highlights

Science highlights in the Planetary Science Division include recent LRO images of impact melts on the lunar surface, flow-like structures that are not volcanic in origin; the total volume of flow material is substantially more than models would predict and has engendered a reassessment of models. Mars water is also being seen at latitudes closer to the equator, particularly in fresh impact craters that expose water ice. MRO's shallow radar instrument, SHARAD, has also provided evidence of glacial ice that is buried beneath the surface. More data are being accrued on asteroid processes and diversity, including evidence of asteroid collision; meteorites from a recent collision have been found to be a combination of stony, primitive and processed objects. These recent events suggest that asteroids can be heterogeneous, and that a single spectral classification may not be appropriate for their classification. Reaccretion of asteroids may occur. Evidence of volcanism on Venus has been obtained from high emissivity signals, suggesting ferric minerals such as fresh basalts- these minerals would have to be young as they would weather quickly in the Venusian atmosphere.

Dr. James Green, Director of PSD, continued the presentation, citing a recent result from Mars Express that suggests solar wind contributes to the loss of Mars atmosphere. Other observations include the result of impact events that trigger avalanches on Mars. In a terrestrial use of Mars technology, the MSL ChemMin instrument is being leveraged by the Centers for Disease Control (CDC) for application to a malarial drug verification technique. Surface differences between Ganymede and Callisto have been noted, suggesting that one satellite has resurfaced itself more frequently over time, perhaps due to impact events. Recent Cassini images have revealed a giant "footprint" of methane or ethane lakes on Titan, analogous to terrestrial lakes and bays.

Dr. Green reported that the PSD FY10 budget ended up with a general reduction of \$18.2M; these reductions were allocated based on principles previously devised by PSD. The reductions took \$4M out of Discovery, \$3M from R&A (due to uncosted funds) and \$11.2M from LADEE. PSS agreed with the approach taken. PSD anticipates several civil servant Program Scientist opportunities at Headquarters this year. The Discovery AO is scheduled for release in June, with proposals due before end of calendar year (CY) 2010. PSD has also received proposals for instruments on ESA's Trace Gas Orbiter for the Mars 2016 opportunity, with selection to be announced by the end of this fiscal year. There will be no funding available for missions of opportunity (MOOs) this year. After GRAIL, Juno, and MSL are launched next year, PSD will attempt to apportion funds for a MOO.

In international proceedings, NASA and the China National Space Administration (CNSA) held a bilateral meeting which focused on persuading China to agree to open data policy. NASA has invited CNSA to participate in Lunar Science Institute (LSI) and International Lunar Network (ILN) activities. NASA and ESA have assembled various joint science teams for future Mars opportunities.

Status of Pu-238

Administrator Bolden recently signed a letter to the Department of Energy's Secretary Chu, updating NASA's estimated need for Pu-238; however, funding to restart domestic production still needs to be approved by Congress as part of the FY2011 Appropriations process. The new Pu-238 requirements are lower than what had been anticipated for human exploration missions to the lunar surface under the Vision for Space Exploration; this new estimate will be reflected in the updated Department of Energy Pu-238 restart plan. Dr. Weiler remarked that the early restart of domestic Pu-238 production remains crucial, as the Pu-238 must be "cured" for three years to allow adequate dissipation of dangerous gamma radiation before it can be processed into a usable form.

Dr. Green noted that the Planetary Supporting Research and Technology (SR&T) program has been brought back into budgetary alignment with 2004 levels, and recognized that instrument development activities could use a boost/rearrangement in funding to support higher-TRL instruments. PSD has also analyzed money spent on objects in the solar system. PSS is establishing a working group to support an SR&T review.

Earth Science Subcommittee Update

Dr. Byron Tapley, chair of the Earth Science Subcommittee (ESS) reviewed science highlights of the ESD, most recently the employment of A-Train satellites to view Iceland's volcanic eruption, primarily via Aqua's and Aura's MODIS and OMI instruments, which provided detailed characterization of the ash cloud. The Ozone Monitoring Instrument (OMI) aboard EOS-Aura and the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard EOS-Aqua fly in formation as part of the A-train.

Dr. Tapley reviewed subjects considered in the March 2010 ESS meeting, including initial planning for a highly constrained budget. ESS has since been assured that Decadal Survey Tier 1 missions are in a healthy state of development (CLARREO; Soil Moisture Active and Passive, ICESat II, and Deformation, Ecosystem Structure and Dynamics of Ice missions) and that foundational and Congressionally directed "national needs" missions (DSCOVR, SAGE-III and GIFTS) now have support from a Congressional augmentation that was directed at ESD earlier this year. The NPOESS issue remains a topic of concern and is an ongoing activity. While the overall picture has greatly improved, ESS remains concerned with continuity of measurements and simultaneity due to the aging of orbital assets, continuing dialogue with the international community, data disparities, uneven application of open-skies policies, and interagency collaboration supporting NPOESS/JPSS, and the potential for an integrated Earth-observation system. A

major focus for the future will be details of FY11 budget request, as well as the ESD Science Plan. The subcommittee has not formally discussed ISS utilization, which is an ongoing topic for consideration.

Earth Sciences Division Update

Dr. Michael Freilich updated the Science Committee on ESD's FY11 \$2.4B augmentation, and provided the Committee with the budget allocation in terms of the year 2000 budget. The division has submitted a plan to the Office of Management and Budget (OMB) and the Office of Science and Technology Policy (OSTP) detailing how the funding augmentation would be allocated. Programs (foundational missions) that are already on track will not have new monies applied to them. The foundational missions, which were on hold 3 years earlier, are now moving toward realistic launch dates. Dr. Freilich noted that once NPP launches, it will become a national meteorological asset.

The augmentation has allowed ESD to move ahead rapidly on the Orbiting Carbon Observatory (OCO-2), which will be launched on a fast track for 2013. The augmentation also allows launch of all four Tier 1 missions between 2014 and 2017, meeting simultaneity requirements, and expanding and accelerating the competitive, PI-led Venture-class program. This funding will further develop selected Climate Continuity missions such as the Stratospheric Aerosol and Gas Experiment (SAGE-III), the Gravity Recovery and Climate Experiment (GRACE) follow-on, and potential additional measurements identified with the United States Global Change Research Program (USGCRP). It will also enable key non-flight activities such as a multi-year carbon monitoring pilot program, expanded modeling, synthesis and computing ability, and expanded geodetic ground network. In addition, with USGCRP, ESD will be identifying and enabling additional Tier-2 missions.

Operating mission status

ESD currently has 13 satellites in operation; 9 satellites are supported by significant international collaborations. ESD is greatly increasing collaborations with ESA and is scheduled to sign an international framework for field campaigns, ground systems, development of combined data products, mission interoperability, and flight missions. This agreement has been greatly facilitated by ESA's decision to join an open-data policy, which will be retroactive. ESD is also collaborating with the Japan Aerospace Exploration Agency (JAXA) on three major initiatives, including a formal agreement to return data from the ALOS satellite through NASA's TDRSS, effectively doubling to tripling the bandwidth of the mission. Collaboration is also under way between JAXA carbon science teams, and GPM. ESD is also collaborating with the French space agency CNES on the SWOT mission (wide swath altimetry for hydrology and oceans), and work package divisions associated with this mission. NASA is also having sustained discussions with the Brazilian space agency INPE on a Global Precipitation Mission (GPM) collaboration, with NASA providing the GMI-2 instrument, accommodation costs and data downlink, and INPE providing spacecraft and launch services. Germany has agreed to provide GRACE funding through the end of mission, and is discussing the GRACE follow-on with NASA. The Argentinean agency CONAE is collaborating with NASA on Aquarius, with NASA providing instrument and launch, and CONAE providing the spacecraft and 7 instruments.

GLOPAC, an atmospheric chemistry and dynamics experiment, is using a Global Hawk high-altitude unmanned aerial vehicle (UAV) to study trace gases in the troposphere and stratosphere, including fragments of the polar gyre that are migrating to lower latitudes. GLOPAC has made 2 flights thus far, taking vertical profiles of the atmosphere, and confirming that UAV fuel functions properly at very low temperatures. In September, ESD plans to fly the Global Hawks over hurricanes, gaining hours of loiter time over the storms. The next Venture-class AO will incorporate small satellites in late 2011, and the first of an annual set of calls for major ES instruments (\$90M) will be held in 2012.

NASA's Technology Initiative

Dr. Robert Braun, NASA Chief Technologist, presented details of the Agency's recently established Office of the Chief Technologist, first providing some history underlying the impetus for the program. The President's FY11 budget request reflects a heavy emphasis on technology; in addition, for several years, external input from committees, the National Research Council (NRC) and Congress have called for technology development in various forms within NASA, often focusing on the importance of advanced concepts. Drawing on his history in formulating Mars Pathfinder, Dr. Braun noted that this mission had been a game-changer, in that it generated new interest in the exploration of Mars, hence influencing a long series of Mars missions. Dr. Braun also cited Mars microprobe technology development, which helped to support the development of a single-stage atmospheric entry system that is now being considered for Mars Sample Return as an example of success from a "failed" program. He also discussed how technology investments made by ESMD in preparation for development of Orion's thermal protection system, greatly assisted MSL in raising the technology readiness level of the tiled Phenolic Impregnated Carbon Ablator (PICA) heat shield system, which was ultimately selected for flight on the MSL mission. This effort also led to arc jet testing as an indispensable thermal protection system (TPS) tool.

A considerable technology investment will be required for a human Mars mission; it will take about 12 ISS masses in low-Earth orbit (LEO) to initiate one round-trip human Mars mission. Technology development needs to reach a two-mass capacity before one can even begin the discussion for a human Mars mission.

The roles and responsibilities of the Chief Technologist are to function as a principal advisor and advocate to the Administrator; provide communications and up-and-out advocacy for NASA research and technology programs; direct management of the OCT Space Technology program; coordinate technology investments across the agency; and support a portfolio of technology investments enabling NASA to pursue entirely new missions of exploration and discovery. The approach will be to prove the fundamental physics of a particular technology first, followed by a technology demonstration in the relevant environment. OCT will combine ESMD technology pull (propulsion, e.g.) and Space Technology Program technology push, and is seeking disruptive approaches. The effort is to be composed of early stage innovation and foundational research, followed by a steady cadence of technology demonstrations, as well as early investment in long-lead capabilities which will be needed for future deep space and surface exploration missions. Asked about plans for heavy lift options, Dr. Braun replied that while OCT is evaluating options at present, such as aluminum vs. composite tanks), there are no new radical options.

Ideas for technology development within OCT will arise from competition such as requests for proposals, Broad Agency Announcements, AOs, some targeted subjects, and some broader, grand challenges in communication or propulsion. The purpose of OCT will be to advance non-mission focused technology and broadly applicable technology that is of use to multiple customers. Examples of crosscutting technologies may include lightweight structures and materials, advanced in-space propulsion, nano-propellants, lightweight large-aperture space systems, energy storage systems, high-bandwidth communications, inflatable aerodynamic decelerators, and power generation and transmission systems. The office has three divisions: Early Stage Innovation, Game-Changing Technology, and Crosscutting Capability Demonstration. Under the Crosscutting Technology Demonstration division, a new version of the New Millennium program is essentially being stood up. Roadmaps are currently under way to guide these activities, such as for Aerocapture, and Entry, Descent and Landing (EDL) Technology. A renewed emphasis on technology can support NASA as a catalyst for innovation and economic expansion in the U.S., provide support and a pipeline for young talent in the Science, Technology, Engineering and Mathematics (STEM) disciplines, and meet broader national needs in energy, weather, health and

wellness, Earth science, and national security.

Asked how OCT would interface with SMD, Dr. Braun explained that the NASA Technology Executive Council will be the vehicle for integrating the Space Technology program with SMD. The council will include representation from SMD, and will meet regularly and work to resolve discrepancies, reduce redundant efforts, etc. Dr. Braun felt there would be little chance of a Technology Directorate being formed, noting that each directorate has been doing a good job in its own area; the missing portion has been the cross-cutting technologies. As for international collaboration, International Trafficking in Arms Regulations (ITAR) remains an obstacle and is being revisited by the Administration. OCT will have to learn to work with restrictions, especially with intellectual property (IP). Corporate IP will also be an issue. OCT plans to deal with the issue by calling for teams and thereby incentivizing collective work. Some concrete metrics for OCT are in development, such as the number of ideas that make it to fruition (long-term); how many crosscutting capability demos get into future NASA missions, and so-called "failure" metrics. Dr. Braun welcomed competition in open calls in what he thought of as Discovery-class calls that anyone can propose to, and that are graded on the potential for technology advancement instead of science value.

Q&A with SMD AA

Dr. Weiler reviewed notable SMD events of the last two months. SMD staff has spent a fair amount of time briefing Congress, including the Senate and House Authorization Committees. Dr. Weiler reported that the briefings were characterized by a good exchange of information and little negativity. SMD is also busily communicating with newly established non-SMD programs, such as OCT's Space Technology Program. The directorate has held bilateral meetings with ESA, and has recently agreed to meet semiannually to continue to define cooperative missions. SMD has established a new Joint Agency Satellite Development office to manage the JPSS mission for NOAA, with eleven new billets, some of which are spread out in support and budget offices. Dr. Lean asked which agency would analyze data records for JPSS. Dr. Freilich responded that while data analysis is a NOAA role, ESD may decide to put resources into it. There will be science input from NASA in a formal way, which can be passed to NOAA and negotiated. The data analysis and stewardship would reside at Goddard Space Flight Center, according to the draft structure.

SMD has received the NRC report on Revitalizing NASA's Suborbital Science Program, and continues to work with OMB/OSTP and DOE on the Pu-238 issue. Dr. Weiler felt that the Pu-238 issue may actually be resolved. SMD is still in the process of responding to President Obama's re-vectoring speech at the Kennedy Space Center, and must continue to weigh the potential effects of a Continuing Resolution, should the FY2011 budget not be approved before the start of the fiscal year. Asked about the role of the Chief Scientist, Dr. Weiler replied that it would be a staff position, without resources for building and launching programs. The primary role of the Chief Scientist would be up and out be as a spokesperson for NASA. NASA is seeking a respected senior researcher/faculty member, a functional analog to the Chief Engineer. A Chief Scientist could revitalize life sciences/microgravity on ISS, a community that had largely disappeared in recent years. Dr. Huntress agreed that this entire community must be reconstituted.

April 21, 2010

Astrophysics Update

Dr. John Morse, Director of the Astrophysics Division (APD) briefly reviewed the administrative status of the Astrophysics Subcommittee (APS). Dr. Morse welcomed new members to the APS, including incoming Chair Dr. Alan Boss, as well as newly sitting members Drs. Lou Allamandola, Mary Beth Kaiser, Vicky Kalogera, and Steve Ritz.

APD Science Results

Dr. Boss presented the latest science results from the APD. HST detected a brown dwarf star with a planetary mass companion of 5-10 Jupiter masses, with a Saturn-like orbit in distance. Herschel's HIFI instrument detected a spectrum of water and organics in the Orion nebula, including dimethyl ether, methanol, CO, and SO₂, indicators of life's precursor molecules. Spitzer warm phase imagers have turned to a search for time variability of young stars in Orion, following 1500 young stars over a time series in the hope to see evidence of rotating disks, etc. The Fermi (formerly GLAST) telescope, in studies of the radio galaxy Centaurus A, has managed to resolve gamma rays correlating with known radiofrequency emissions. Dr. Burns viewed the Fermi results as spectacular and model-transforming. The Wide-field Infrared Survey Explorer (WISE) detected interesting chemical processes in the Berkeley 59 cluster in the Cepheus region, where a supernova remnant lies, constituting what might be a Solar System analog, triggered by a supernova shockwave.

Dr. Morse resumed the presentation, highlighting recent programmatic events. JWST passed CDR at the mission level last week, and will undergo a programmatic review in May. HST celebrates its 20th birthday in 2010. APS is working on a response to the NRC study of NASA's suborbital research capabilities. The study has recommended an extended duration sounding rocket, short duration experiments, ultra long duration balloon capability (100 day campaigns at mid-latitudes), and campaigns at both polar regions. A Senior Review of operating missions was held in early April, covering 11 missions: RXTE, Suzaku, Spitzer, Chandra, WISE, Planck, XMM-Newton, INTEGRAL, GALEX, WMAP, and Swift. A final report will be delivered by late April. WMAP will be terminated. Dr. Lean asked if terminated missions could be revived. Dr. Morse felt this to be unlikely, as the budget is heavily oversubscribed. He did note, U.S. scientists can still write proposals to international missions.

The Astronomy and Astrophysics Decadal Survey (Astro 2010) is expected to be released in September 2010. APD has sent a letter to Astro 2010 committee describing potential partnerships on ESA's Cosmic Vision M-class mission candidates, including Euclid (dark energy mission) and PLATO (exoplanet mission). Contributions of up to 20% of the total mission value to ESA can be made through a NASA-sponsored instrument AO, providing hardware to spacecraft or ground/launch segments, or U.S. participation on ESA teams. All data from these efforts would be archived and made accessible after proprietary periods (i.e. primary mission phase, usually one year). The data policy would be determined by peer review. In the meantime, NASA has dispatched two scientists per mission to evaluate science payloads, and engineers to examine technical aspects of the ESA missions. NASA will receive the Decadal Survey results before committing to Euclid or PLATO. JDEM, Space Interferometry Mission (SIM) and related efforts will continue this year, pending Decadal Survey results. Scientific priorities that are not highly ranked will not be pursued. Dr. Morse noted that JDEM and SIM currently have no budget in FY11. Dr. Weiler interjected that APD is trying to give the Decadal Survey realistic options, given the European initiative in dark energy. Dr. Morse added that launch of JWST must occur before a significant budget wedge opens up for new missions in APD; this has been communicated to Astro 2010. The division is now spending ~ 40% of its budget on JWST and has a much more balanced program at present.

Kepler data release policy

During the APS meeting addressing this issue, Dr. Boss recused himself from the discussion, and Dr. John Huchra acted as APS chair in addressing the Kepler data release issue. Dr. Huchra described the issue: The Kepler science team has requested a revision of Kepler data release. Guiding principles for data release include fairness to the team, interest in assuring high-quality data (data verification), and a desire on the part of NASA and the community to release data in a timely manner. Astro 2010 is expected to make specific recommendations regarding exoplanets, which are currently a topic of high interest. APS disagreed strongly that the proprietary period for Kepler results be extended, as this would set a bad

precedent and reduce scientific output. APS ultimately recommended, in a non-consensus decision, that a compromise Option #3 be adopted as a means of retaining the original intent of the Kepler agreement; it preserves the letter of original agreement to have one observing season to confirm interesting targets. Option 3: Data for majority of Kepler target stars released according to baseline schedule, with science teams allowed to extend the proprietary period during a limited number of defined periods per quarter. Dr. Huchra commented that because there is no way to absolutely rule out false positives, it is not worthwhile to sequester data for an extended period. Dr. Burns supported the APS conclusion and the Science Committee concurred. Dr. Huntress agreed to include this concurrence as a finding for the committee.

Dr. Huntress asked Dr. Morse if APD had considered ISS utilization. Dr. Morse explained that ISS utilization is already allowed in ROSES. APD is also in the process of selecting scientists to participate in the development of a JAXA instrument for ISS. Proposals for ISS payloads were received as partner Missions of Opportunity (MO) in response to the Small Explorers and MO 2007 solicitation. The only MO selected was the Astro-H mission, which is not an ISS mission. Dr. Weiler recommended that proposal pressure determine the extent of science involvement in the ISS. Dr. Burns felt that ISS utilization principles should be resolved at the Science Committee level, pending individual Science Subcommittee discussion results.

Heliophysics Update

Dr. Roy Torbert, Chair of the Heliophysics Subcommittee (HPS), reviewed Heliophysics science highlights. Recent data has been acquired on the origins of solar energetic particles (SEPs) helping to better understand this hazard for manned spaceflight and satellite. Observations from three missions have revealed new data on compositional variability (ratio of Fe to O) of SEPs relating to the solar region that produced the particles (active region or coronal hole), and have identified a new input for models to help predict the severity of the SEP radiation hazard.

Participants at the Yosemite Reconnection Conference presented a suggestion, in a new simulation by Daughton *et al.*, that reconnection may be explained by the geometry of “islands” on the solar surface, a possible solution to the riddle of reconnection. If confirmed by Magnetospheric Multiscale (MMS) mission observations, these findings would represent a major step forward.

Dr. Torbert reviewed HPS findings from the subcommittee’s latest meeting. Notably, great concern had been expressed about the loss of the HPD Guest Investigator program and its negative impact on the Great Observatory (GO). Joe Bredekamp noted that HPD shares the concern and will make every effort in the formulation of the FY 12 budget submission, as well as in the potential execution of the FY 11 budget to mitigate this consequence. Dr. Paul Hertz added that the cuts to the GI program resulted from a direct Congressional action. HPS also registered a finding on budget constraints, noting a significant hit to each mission line for detailed orbital conjunction analysis (collision avoidance). As a result, SMD has decided to review the requirements on a division-by-division basis, to be followed by an SMD-wide response. HPS also stated its strong endorsement of frequent launch opportunities offered by the Explorer program. Dr. Feeley reminded the Science Committee of its previous recommendation to allow the AA maximum flexibility in making a decision on the Explorer AO.

HPD Status

Mr. Joe Bredekamp presented the HPD status, standing in for Director Dr. Richard Fisher, beginning with recent mission events, the most prominent being the successful launch of the Solar Dynamics Observatory. All the instruments are now turned on and performing well, and the First Light Press Briefing held later on April 21, 2010, is expected to generate exciting prospects for the science produced by this mission. The other mission under development in the Living with a Star (LWS) Program,

Radiation Belt Storm Probes (RBSP) continues to progress. BARREL, a balloon under flight campaign for RBSP, completed both a Preliminary Design Review (PDR) and Confirmation Assessment in March. Also within LWS a Solar Probe Plus mission was approved for formulation and a Phase A contract is expected to be awarded by April 30, 2010. The Magnetic Multi-scale (MMS) mission under development in the Solar Terrestrial Probe program continues to progress heading to the Critical Design Review (CDR) this summer.

A potential partnership with ESA on the Solar Orbiter candidate mission is being considered for selection under their Cosmic Vision program. The four NASA-provided instruments have reviewed accommodations/interface requirements with ESA/Astrium and a meeting will be held in June to confirm the Solar Orbiter Payload Complement Programmatic Readiness.

The HP Great Observatory fleet of 16 operating missions with a total of 27 spacecraft is expected to soon add SDO to the complement. The biannual Senior Review of those operating missions is being held this week to consider proposals for extending the missions based on science merit and value. The Panel faces some serious deliberations in view of the tight constraints on budgets.

In the Sounding Rocket Program managed by HPD for SMD, an issue with the Black Brant Thrust Termination Systems necessitates an upgrade and inventory resupply, which in turn will require re-planning the summer schedule. HPD is also working the response to the recently-delivered NRC Suborbital Study report.

Mr. Bredekamp then provided two additional HPD science highlights. The first was observation of an eruptive prominence on the limb of the Sun as a result of the largest coronal mass ejection event seen in several years, as viewed from 3 spacecraft (Stereos A and B, and Solar and Heliophysics Observatory (SOHO)). This offers key insight into the three dimensional nature of the magnetic field expansion into the solar system. Mr. Bredekamp also displayed a sneak preview of one of the SDO composite images to be released that afternoon at the First Light Press Briefing. This preliminary 3-color composite of a small active region near the west limb of the Sun gives a sense of the unprecedented spatial, temporal, magnetic field, surface tomography, and temperature resolution, and the potential to vastly change our understanding of the Sun and its processes.

In response to a prior request, Mr. Bredekamp reviewed the SDO life cycle cost trace, from pre-formulation to the current estimate. Since Confirmation in May, 2004 there has been a total increase of 9.4% in cost and 22-month slip in schedule attributable to a number of factors, including a 14-month delay waiting for a place on the Atlas-V launch vehicle manifest. Dr. Lean asserted that SDO had in fact grown by a factor of three over initial estimates given to the Science Definition Team, and that these increases must be viewed as a true "cost of doing business." Dr. Huntress commented that missions need to identify cost categories in the pre-formulation phase, and spend enough money in pre-Phase A and Phase A to better articulate cost expectations.

Lessons Learned from the New Millennium Program

Dr. Ray Taylor presented a summary of lessons learned in the former New Millennium Program (NMP), based on materials derived from a formal assessment performed by JPL. NMP's original role had been to advance low-TRL (technology readiness level) technologies through flight validation in space, or from TRL-1 to TRL-7 (prototype demonstration in a space environment) or TRL-9 (actual system flight proven through successful mission operations). Through its lifetime, NMP validated a significant number of technologies, one of which is still in progress (ST-7 micronewton thrusters for the LISA-Pathfinder mission). Five of six projects flown during NMP met their full mission criteria for success, and nearly all technologies flown were validated to TRL-7. Eight projects were terminated for cost growth/maturity

issues. NMP's technology review boards, independent of the projects, were considered key in ensuring the validity of NMP achievements.

Counted among NMP successes were: an increased ability to assure reliable access to high-science value areas, miniaturization of instruments, and the ability to send more science payload masses to planetary bodies with atmospheres. Examples include Deep Space 1 ion thrusters, which were employed on the Dawn mission, as well as transponders from the same project that were used on Dawn, the Mars Exploration Rovers, and MRO. Constellation operations from ST-5 helped to enhance SDO, GLAST and LRO.

Access to space presented a major impediment to progress in NMP. In particular, partnering with the Air Force was viewed as having caused programmatic risk through a multiyear slip. Dr. Taylor noted that ESPA (vehicle-modifiers for payloads) rings could mitigate this risk in the future, expanding access to other rockets. Dedicated missions for subsystem validations within NMP were also considered too expensive, in addition to the programmatic constraint inherent in only addressing technologies which require validation on-orbit.

In summary, NMP demonstrated the benefit of advancing technologies to TRL 6-7 levels. Dr. Huntress remarked that there is still a need to validate technologies outside of the OCT office, and asked whether SMD would have access to OCT to validate technologies. Dr. Taylor reported that SMD now has an interface (Michael Moore) with OCT, and that connections are continuing to be made. He added that potentially large investments in ESMD will also be made, and that concepts and issues will also be reflected in the new Technology Roadmap. SMD may be able to leverage other efforts besides OCT. Mr. Moore said he hoped to have a more crisp presentation of these developing relationships by the next meeting of the Science Committee. Dr. Burns asked if there were a way to connect the OCT more closely with the Explorer program. Dr. Torbert commented that Explorer was insufficiently risk-tolerant for technology development efforts. Dr. Huntress observed that NMP suffered from the conflicting requirements between science and technology. Mr. Moore noted that OCT will wrestle with science vs. technology requirements in the Technology Roadmap, recognizing that NASA technologies tend to have to be pushed. He also noted that a coherent set of needs and requirements must be constructed, which also must meet the multiple applicability requirements of OCT. ISS as a TRL test bed was considered to be too costly.

ISS Utilization

Mr. Mark Uhran presented a briefing on the continuing utilization of the International Space Station (ISS). Because the President has proposed to extend ISS lifetime beyond 2015, SOMD is looking at ways to extend its lifetime beyond 2020. ISS utility, however, must first be thoroughly characterized before a final lifetime is determined. A total of \$70B has been invested globally as ISS enters the next decade of utilization. STEM education is also increasingly part of the ISS program. There are roughly 34 international payload racks (23 U.S. payload racks) distributed across ISS. Station-wide, there are on the order of 50-60 payload sites, and each site can accommodate a variety of experiments. Overall, there is capacity for several hundred payloads on the facility. Using external sites such as Express Logistic Carriers (ELCs; 9800 lbs capacity) and the JEM Exposed Facility (5500 lbs and a 1.5m³ volume capacity), the ISS is designed so that payloads can be turned over on a regular basis.

There are a variety of ISS nodes available for docking. The ISS program is working to make these docking ports completely interchangeable so that any country's vehicle can dock at one of them. The capacity as a test bed is ISS's most valuable characteristic; it is essentially a deployed permanent bus, is resupplied on a quarterly basis, and is continually crewed. ISS can accommodate class D hardware, and as mission success criteria are less stringent than for most missions at NASA, ISS projects tend to be less

costly as well. Russia's Soyuz vehicle is viewed as the crew taxi, and the Progress vehicle as the hauling truck. NASA has committed to the Russians through 2012 for these capabilities. In the meantime, the European ATV and Japanese HTV have each made a successful maiden flight to ISS, while the U.S. companies Space X and Orbital Sciences have yet to make their first vehicle demonstration flights. Currently, the only vehicle with appreciable downmass capability (~ 3.0 metric tons) is the Dragon, and Soyuz has only minimal (~ 75 kilograms) downmass capability.

SOMD is fully budgeted for cargo resupply through 2015. Hence, transportation to the ISS is paid for or bartered on transfer vehicles, and is contracted as an annual service. SOMD is the primary contact for flight opportunities or proposal development. Mr. Uhran recommended himself or Paul Hertz as contacts for interested parties. The ISS budget allows for an additional 3 metric tons per year, beyond the requirements for upmass to maintain the Station and carry out the NASA research program. Responding to a question, Mr. Uhran maintained that manifesting is the same challenging process it has always been.

ISS is a platform for Earth observation, from which one can see 75% of the world's land surface. It is not an ideal platform for some viewing purposes, due to low frequency jitter, however environments are well defined and under continual evaluation. ISS can capture changes on Earth's surface, such as thinning ice in Siberia. It can also be used as a platform for astronomical observation. At present a "Top 100 NASA Ideas" for technology demos on ISS is in the process of downselection. Mr. Uhran displayed a brief animation of the ISS and its environment.

Mr. Uhran briefly reviewed elements of the micrometeoroid/meteor and orbital debris (MM&OD) system that helps to shield ISS elements from space debris, explaining that the program also receives information from other orbiting assets to avoid collisions. Dr. Lean asked about ISS overhead costs associated with its human rating. Mr. Uhran replied that the program has tried to make overhead less onerous through standardization, and has improved the safety certification process, but allowed that human-rated costs were still a challenge. Proposed experiments bear the cost of the safety certification. ISS has briefed OMB and is preparing to brief Congress on NASA plans to pursue an external nonprofit management structure for non-NASA uses of the ISS; NASA will continue to manage its own missions in-house. NASA uses about 50% of the ISS capacity, and most of the non-NASA interest to date exists on the interior of the facility. ISS now needs to plan on how to reserve capacity on the exterior. Mr. Uhran cited an excellent ISS success story in which microgravity experiments on methicillin-resistant *Staphylococcus aureus* (MRSA) led to the creation of a target vaccine against MRSA, a major cause of mortality and morbidity in U.S. healthcare facilities. Orbital effects on cell culture and genomic expression also has implications for plant cultivars and astrobiological philosophy.

Asked about logistics for carriers to the ISS, Mr. Uhran noted that a move from Space Shuttle usage to a commercial supplier within 12 months would be ideal. There are current opportunities on the Japanese vehicle, and Europe is also lined up to provide cargo delivery services on its vehicle.

Discussion

The committee discussed action items for each subcommittee, particularly for compilation of science that can be performed on ISS, including estimated costs. Dr. Greeley referred to previous brainstorming sessions on microgravity, which also dealt with maturation of technologies and development of sample acquisition and handling techniques for the asteroid environment. Planetary protection is also an issue for sterilization of components in space. Dr. Tapley felt that for Earth Science, an altimeter on ISS might be helpful for niche experiments. Dr. Torbert noted that ISS did not fly in an especially attractive orbit for Heliophysics. Dr. Hertz reminded committee members that information on ISS costs, environment, and logistics is available in the AOs, on the web; these data are already available in the upcoming Explorer AO, and other relevant information resides with the Executive Secretary of each Science Subcommittee.

The Science Committee took time out to watch the first-light press conference for SDO.

Public comment period

No comments were noted.

Findings and recommendations

The committee discussed various findings. There was concurrence on taking the Pu-238 issue to the level of the NAC. A finding on the International Mars program was directed to SMD. The concern over uncosted carryover was deferred to the general community. A finding on a lunar sciences proposal was conveyed to Dr. Green. A recommendation about robotic precursor Roadmap collaborations was raised to the level of the NAC. Dr. Braun supported a finding on endorsement of the OCT and flight technology program to be taken to the NAC; Dr. Weiler suggested emphasizing the importance of peer review in this potential finding. An APS finding on Kepler data policy was reviewed and approved for consideration by the NAC.

The committee considered, and approved, an invitation to Dr. Ron Sega, the Chair of the Space Studies Board (SSB) study on cost growth in NASA's Earth and Space Science missions, to attend the next meeting and brief the committee on the NRC study.

Dr. Huntress suggested that the cut in the HPD Guest Investigator program should be dealt with at the community level and through appropriate interaction with the relevant Congressional staff. He added that the committee could direct the finding at SMD, but that one could not expect an outcome from that finding.

The agenda for the next meeting was to include discussion on costs based on SSB reports, ISS utilization based on Subcommittee reports, a ESMD briefing on Exploration-Science cooperation; a discussion of the Congressional budget pass back (assuming it has occurred in the interim), and a briefing from Mr. Michael Moore on SMD interaction with the OCT.

Dr. Huntress thanked Dr. Weiler for his time spent with the SC, and adjourned the meeting.

Appendix A Attendees

NAC Science Committee members

Wesley Huntress, Carnegie Institute, *Chair*
Byron Tapley, University of Texas, *Vice Chair* and Chair Earth Science Subcommittee
Jack Burns, University of Colorado
Ronald Greeley, Arizona State University, Chair Planetary Sciences Subcommittee
Judith Lean, Naval Research Laboratory
Eugene Levy, Rice University, Chair Planetary Protection Subcommittee
Roy B. Torbert, University of New Hampshire, Chair Heliophysics Subcommittee
T. Jens Feeley, NASA Headquarters, *Executive Secretary*

NASA Attendees

Marcus Allen, NASA Headquarters
Padi Boyd, NASA Goddard
Joe Bredekamp, NASA Headquarters
Janice Buckner, NASA Headquarters
Orlando Figueroa, NASA Goddard
Michael Freilich, NASA Headquarters
James Green, NASA Headquarters
Hashima Hasan, NASA Headquarters
Debbie Hollebeke, NASA Goddard
Paul Hertz, NASA Headquarters
Tibor Kremic, NASA Glenn
Tony Lawson, NASA Goddard
David Leisawitz, NASA Headquarters
Jon Morse, NASA Headquarters
Marian Norris, NASA Headquarters
Douglas McCuiston, NASA Headquarters
Thomas Moore, NASA Goddard
Michael Moore, NASA Headquarters
Charles Norton, NASA JPL
Bill Oegerle, NASA Goddard
Sue Pierpoint, NASA Headquarters
Rita Sawbruna, NASA Goddard
James Slavin, NASA Goddard
Ray Taylor, NASA Headquarters
Harley Thronson, NASA Goddard
Mark Uhran, NASA Headquarters
Azita Valinia, NASA Goddard
Lelia Vann, NASA Langley
Ed Weiler, NASA Headquarters
Amy Walton, NASA Headquarters
Nicholas White, NASA Goddard
Greg Williams, NASA Headquarters
Dot Zugar, NASA Goddard

Non-NASA Attendees

Alan Boss, Carnegie Institution, Chair Astrophysics Subcommittee

Randall Correll, Ball Aerospace

Eric Hand, Nature

Garrett Saito, Lewis Burke Associates

Ana Wilson, Harris Corporation

Joan Zimmermann, Harris Corporation

Appendix B
NAC Science Committee Membership

Wesley T. Huntress, Chair
Emeritus
Geophysical Laboratory
Carnegie Institution of Washington

T. Jens Feeley, Executive Secretary
Science Mission Directorate
NASA Headquarters, Washington, D.C.

Alan P. Boss (pending)
Department of Terrestrial Magnetism
Carnegie Institution of Washington

Jack O. Burns
Center for Astrophysics and Space Astronomy
University of Colorado, Boulder

Ronald Greeley
School of Earth and Space Exploration
Arizona State University

Noel W. Hinners
Consultant

Charles F. Kennel
Chair, Space Studies Board
Scripps Institute of Oceanography
University of California, San Diego

Judith Lean
Senior Scientist, Sun-Earth System
Naval Research Laboratory

Eugene H. Levy
Professor and Provost, Physics and Astronomy
Rice University

Byron Tapley, Vice Chair
Director, Center for Space Research
University of Texas, Austin

Roy B. Torbert
Space Science Center
University of New Hampshire

Michael S. Turner
Kavli Institute for Cosmological Physics
University of Chicago

Appendix C Presentations

1. *Goddard Space Flight Center Presentation to the NAC Science Committee*, Rob Strain
2. *Investments in the Future: NASA's Technology Program*, Robert Braun
3. *Astrophysics Subcommittee Summary Presented to the Science Committee of the NAC*, Alan Boss, John Huchra, Jon Morse
4. *Heliophysics Status Update to NAC Science Committee*, Joe Bredekamp
5. *Heliophysics Subcommittee Report to the NAC Science Committee*, Roy Torbert
6. *Update on the SMD Science Plan*, Greg Williams
7. *ISS Utilization, Earth and Space Opportunities*, Mark Uhlan
8. *Earth Science Division Update*, Mike Freilich
9. *Planetary Science Division Program Status*, James Green
10. *Planetary Sciences Subcommittee Presentation to the NAC Science Committee*, Ron Greeley and James Green
11. *NAC Science Committee: Earth Science*, Byron Tapley
12. *New Millennium Program*, Ray Taylor
13. *Tropical Glacier Extent Variation in the New World*, Compton Tucker

Appendix D

**NAC Science Committee
April 20-21, 2010
GSFC, Building 1, Room E100**

Agenda

Day 1 (Tuesday, April 20)

8:30-8:40am	Remarks and Announcements	Huntress, Feeley
8:40-8:50am	Center Welcome	Strain/Figueroa
8:50-10:00am	GSFC Overview	Strain/Figueroa
10:00-10:15am	Break	
10:15-11:00am	Science Plan	Williams
11:00-11:45am	Discussion	
11:45-12:45	Working Lunch/Science Talk Earth's ice in a time of climate change	Tucker, Markus
12:45-1:30pm	Planetary Science	Greeley, Green
1:30-2:00pm	Discussion	
2:00-2:45pm	Earth Science	Tapley, Freilich
2:45-3:15pm	Discussion	
3:15-3:45pm	NASA's Technology Initiative	Braun
3:45-4:00pm	Discussion	
4:00-5:00pm	Q&A with SMD AA	Weiler
5:00pm	Adjourn	

**NAC Science Committee
April 20-21, 2010
GSFC, Building 1, Room E100**

Agenda

Day 2 (Wednesday, April 21)

8:30-8:45am	Remarks and Announcements	Huntress, Feeley
8:45-9:30am	Astrophysics	Boss, Morse
9:30-10:00am	Discussion	
10:00-10:10am	Break	
10:10-10:55am	Heliophysics	Torbert, Bredekamp
10:55-11:15am	New Millennium Program	Taylor
11:15-11:45am	Discussion	
11:45 – 1:00pm	Lunch on Own	
1:00-1:30pm	ISS Utilization	Uhran
1:30-1:45pm	Discussion	
1:45-2:15pm	Public Comment	
2:15-3:00pm	Findings and Recommendations	
3:00-3:10pm	Final comments	
3:10pm	Adjourn	

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Appendix A- Attendees

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Appendix D- Agenda

*Prepared by Joan M. Zimmermann
Harris Corp.*

Welcome and Introduction

Dr. Wesley T. Huntress, Chair of the NASA Advisory Council (NAC) Science Committee, opened the proceedings, thanking the director of the Goddard Space Flight Center (GSFC) for hosting the meeting. T. Jens Feeley, Executive Secretary made some brief logistical announcements.

Dr. Huntress alluded to President Obama's April 15, 2010, visit to the Kennedy Center, welcomed the new NASA funding contained in the FY11 budget request, as well as a clear plan with timeframes for destinations. He briefly reviewed three recommendations that had been transmitted to NASA Administrator Charles Bolden, namely strong NAC Science Committee support for the development of a new technology program, a proposed re-initiation of Pu-238 production in the U.S., and the establishment of various new NAC Science Subcommittee analysis groups.

Goddard Space Flight Center (GSFC) Welcome

Dr. Rob Strain, Director of Goddard Space Flight Center, briefly addressed committee members, noting that GSFC had celebrated its 50th anniversary in 2009, which had been one of the center's busiest years in launch schedules. In 2010 thus far, GSFC has supported the successful launch of the Solar Dynamic Observatory (SDO) and the latest Geostationary Operational Environmental Satellite, GOES-P. The center is currently in the midst of a hiring campaign to bring in younger staff, addressing the demographic challenge of a rapidly retiring science and engineering community. Fifty percent or more hires for GSFC are slated to be fresh-outs (terminal degree plus 3 years).

GSFC has supported over 300 Earth and Space system missions in its history. GSFC also oversees the Wallops Island suborbital launch facility in Virginia, the Independent Verification & Validation Facility in West Virginia, ground stations at White Sands, and the Goddard Institute for Space Science (GISS) in New York. At present, the center employs approximately 3200 civil servants and over 5400 contractors on site; two-thirds of this population is comprised of scientists and engineers. Mr. Strain introduced GSFC senior staff, Dr. Orlando Figueroa, Deputy Director for Science and Technology, and Dr. Nick White, Director of the Sciences and Exploration Directorate.

GSFC is addressing three major initiatives: the James Webb Space Telescope (JWST), which completed a mission critical design review (CDR) the previous week. The center is also in the process of standing up an office to support NASA Headquarters (HQ) in the newly formulated Joint Polar Satellite System (JPSS) program, formerly known as NPOESS. GSFC is also engaged in mission collaborations with academia and other centers such as Langley Research Center (Climate Absolute Radiance and Refractivity Observatory; CLARREO), Ames Research Center (Lunar Atmosphere and Dust Environment Explorer; LADEE), and the Jet Propulsion Laboratory (Mars Science Lander; MSL). The center is providing a critical instrument for MSL, a laboratory suite called Sample Analysis at Mars (SAM). Asked if the center suffered any restrictions on collaborating with universities, Mr. Strain responded that there were none that he is aware of. GSFC is free to join, lead, or support science teams at other institutions and attempts to be responsive to a variety of scientific initiatives. Dr. Ed Weiler, Associate Administrator of the NASA Science Mission Directorate (SMD) clarified the term "support" in this context to signify manpower, laboratory usage, etc., and not funding.

Dr. Judith Lean asked about the status of full-cost accounting (FCA) at NASA. Mr. Strain noted that NASA has proposed to resume its unified labor practices and has done some planning to be ready to implement this practice. The earliest implementation of such a change, pending approval, would be FY11. Dr. Weiler felt there was a 70-80% likelihood that this would occur, and commented on the amount of management time spent addressing Center staffing levels (specifically Available for New Work or AFNW reviews) in recent years.. Dr. Byron Tapley asked if there were any obstacles to a zero-funded contract

that would allow the transfer of funds between institutions. Dr. Weiler felt that most contracts were already covered by the Space Act. Other possible collaborations could take the form of staff-sharing, student mentoring, work on joint research and development (R&D) activities, leveraging of activities, office space, and even parking.

Dr. Figueroa continued the presentation, noting GSFC's contribution to NASA's diverse mission portfolio, and particularly its contribution to the 2006 Nobel Prize in Physics that was awarded to NASA's Dr. John Mather. GSFC has significant capability throughout SMD, in all of its four disciplines of Astrophysics, Heliophysics, Earth Sciences, and Planetary Sciences. In the last few years, an unprecedented amount of work has passed through the center, including the Fermi Gamma-Ray Space telescope (formerly GLAST), the National Oceanic and Atmospheric Administration (NOAA) N-Prime mission, the Orbiting Carbon Observatory (OCO), the Lunar Reconnaissance Orbiter (LRO), and as previously mentioned, SDO. The Glory mission will be launched in November 2010. In the near-term, GSFC will be supporting the LADEE mission to the Moon, ICESat II, NPP (a preparatory mission for JPSS), Glory-Magnetospheric Multiscale (MMS), the Gravity and Extreme Magnetism Small Explorer (GEMS), the LandSat Data Continuity Mission (LDCM), next-generation Tracking and Data Relay Satellite System (TDRSS), the delivery of the SAM instrument to MSL, the Mars Atmosphere and Volatile Evolution (MAVEN) mission, and the Joint Dark Energy Mission (JDEM) mission definition activities. The last two years have presented some challenges, but GSFC has been successful in winning new missions, providing instruments and supporting other mission activities. The center views itself as a steward and enabler for the entire scientific community. Dr. Huntress commented on the growing trend of Planetary activity at GSFC and asked if there was a conscious strategy to carve a niche in Planetary missions. Dr. White responded that the center was indeed building on natural extension to Planetary science through open competition, and its successful history in Planetary missions. Dr. Huntress noted that entry probes might be a good area of concentration for the center.

Dr. Lean asked if GSFC would absorb any commitments to JPSS. Dr. Figueroa explained that the leadership for JPSS resides in NOAA, and that NASA would function as an implementer, also providing research, instruments, data analysis, and validation/calibration activities in supporting the NOAA effort. Asked when a long-term plan would emerge, Dr. Figueroa responded that NASA is in the process of helping to define the way forward and determining the roles of instruments- the focus until recently has been on establishing the JPSS program office and minimizing downtime between launches. Mr. Strain added that NASA is also trying to help NOAA mitigate data gaps as the mission has begun to divide its time between day and night orbits. It is not yet known what the Department of Defense (DoD) plans to do in its share of the mission. NOAA also lacks funding until FY11. Dr. Tapley observed that while there is a great deal of relief in the mode of implementation, the essential requirements are still unclear. Dr. Figueroa conceded that competing requirements have been a challenge; to this end, NASA has been working on strengthening scientific capabilities and relevant instruments for the morning orbit; this is still in the formative stages. In addition, the Agency has been diligently working to keep NASA's Earth Sciences Division and JPSS separate. Data stewardship is being sorted out instrument by instrument, and data set by data set.

Dr. Figueroa reported that the center is working hard to deliver the very complex JWST, methodically addressing all the challenges, and looking toward a successful launch in 2014. Dr. Burns asked if thought were being given to potential service missions to JWST. Dr. Huntress and Dr. Weiler agreed that JWST was not intended to be serviced, given its distant orbit at Lagrange Point 2. Dr. Weiler added that such servicing would be too costly, noting that the total Hubble Space Telescope (HST) cost, has been roughly \$18B, a substantial portion of which is attributable to its servicing-related costs (including Shuttle launches and related manpower).

Dr. Figueroa enumerated other challenges to JWST, namely verification and validation, as the telescope cannot be tested end-to-end on the ground. Thermal stability and the operating environment for the instruments present a significant challenge to the project, and create stress on the programmatic level as well. The Ariane V load measurement have been fluctuating, leading to frequent re-analysis, and pushing the capabilities of centers and partners. In answer to a question on the rationale for JWST's placement at the Sun Earth L2 point, it was explained that Earth's infrared signature was too bright at closer orbits; JWST can also observe the sky 100% of the time, unoccluded by Earth, in a benign thermal environment. Dr. Weiler also expressed great confidence in Dr. Figueroa and Dr. Gene Oliver as historically successful engineers.

Within GSFC Heliophysics, SDO, which endured a waiting period of more than a year, is already gathering good science data after its February 2010 launch. SDO's minimum lifetime threshold is 3 years. Dr. Weiler felt there was no reason SDO would not last longer than 3-5 years, given the history of NASA engineering; SOHO, for example, has been in operation since 1996. Thus far SDO has had no technical issues. Dr. Weiler disapproved of the misinformation about SDO's cost growth. Dr. Figueroa agreed, noting that SDO was in fact delivered within 1 or 2% of the intended cost, if one factors out the cost of launch delays and programmatic irregularities.

GSFC Earth Sciences is focusing on the Global Precipitation Measurement (GPM) mission, and is also supporting the ICESat 2 mission. In its support of Planetary Sciences, the center is highly focused on delivering SAM to the MSL. SAM will be the most sophisticated instrument suite ever to land on another planet, and will make unprecedented biochemical measurements *in situ*. Engineers are currently struggling with a high-rpm pump, which is scheduled for delivery in December 2010; Dr. Figueroa expected the problem to be solved on schedule. Dr. Burns asked how GSFC was planning to support Exploration. Dr. Figueroa replied that GSFC was supporting four Exploration Systems Mission Directorate (ESMD) teams on robotic scouts, robotic precursors, flagship technology demonstrations, and at Wallops Island, viewing these efforts as preparatory science for addressing exploration-specific questions. Dr. Weiler interjected that robotic precursors are not science missions, and thus not a purview of SMD. LRO and LADEE are also not science-driven missions. He added that SMD would not be funding ESMD activities, the International Space Station (ISS), or other non-scientific programs within NASA. Dr. Figueroa explained that in lieu of funds, GSFC provides support to ESMD teams by offering GSFC strengths in avionics, extravehicular activity (EVA) tools, and instruments to support human exploration, focusing on science through competition. Dr. Weiler added that this is a sensitive issue regarding programs and missions, and that HQ ultimately decides which centers get missions. Mr. Strain noted that rather than building capabilities for Exploration, GSFC would participate where it was deemed fitting. Dr. Eugene Levy asked for clarification in how NASA decides what new capabilities are needed. Mr. Strain explained by way of example that GSFC would not lead a flagship mission, but would stick to its niche, and assessing individual cases. Dr. Levy suggested, given the ambitions of the space program to expand the envelope, that NASA inventory its capabilities and decide which ones to sustain and build.

Dr. Huntress took an action to invite Mr. Doug Cooke to the next Science Committee meeting to crystallize the concept of Exploration science. Dr. Burns suggested inviting Dr. Laurie Leshin as well. Dr. Weiler noted that the ESMD was considering developing a lander for *in situ* resource utilization (ISRU), and that science could benefit from a radio frequency and optical communications relay on a satellite in conjunction with the lander. Dr. Weiler stated that it was his preference that science participation in ESMD missions would be decided through the Missions of Opportunity (MOOs) competition in the Discovery, New Frontiers and Explorers programs. ESMD missions must be well defined in order to determine what science's role will be. However, SMD is already involved in precursor mission planning, with critical senior staff, serving on ESMD-led teams to define future missions.

Dr. Huntress briefly introduced Dr. Alan Boss as the incoming Chair of the Astrophysics Committee, whose paperwork was in progress at the time of the meeting.

NASA SMD Science Plan

Mr. Greg Williams presented an update on the progress of the 2010 NASA Science Plan, reviewing the schedule as the Plan had gone through successive evaluations by each NAC Science Subcommittee. Feedback has been incorporated and the goal is to publish the Plan by June 2010. Other changes must be incorporated, particularly given the President's address on April 15, 2010 at the Kennedy Space Center. Language has been added, as suggested by the Science Committee, describing a fuller articulation of partnership interfaces and boundaries, a strategy for international partnerships, and an approach to managing cost overruns. The issue of a new technology development plan has been added to the Science Plan's set of challenges, as well as a series of text boxes highlighting cross-disciplinary research. Asked whether the concern over cost overruns had been included in the new language, Mr. Williams explained that this had been addressed by providing resources for early estimations, and a discussion of the impact of the 70% confidence rule (e.g., starting fewer missions). A brief discussion ensued on whether to include details on criteria for cancelling a mission. Dr. Feeley felt that because there are Congressional and Agency limits governing these criteria, the details need not be in the Science Plan. There was general agreement in the Science Committee to the contrary; i.e. that a more detailed description of cancellation criteria be included.

Dr. Burns noted that smaller missions seem to manage costs well, and that the Science Plan should give the Agency adequate credit for this by balancing a statement of cost overruns with a better definition of the problem. Dr. Lean suggested equating increased risk/complexity with increased cost. Dr. Levy commented that NASA exists in part to stretch capacity, such that risk is a virtue if properly understood and managed. Dr. Weiler reminded the Science Committee that NASA's budget request includes a proposed \$1B investment in a new cross-cutting technology development program, which can be used for small, medium and large missions, and which would be managed through the new Office of the Chief Technologist. Dr. Lean recommended distinguishing between unrealized vs. unrealistic expectations. Mr. Williams suggested this be expressed as documenting the difference between expectations and reality.

Also in response to feedback, the Science Plan has revised its science questions and objectives, and has modified a statement on Exploration Science to a text box summarizing how SMD science contributes to Exploration. Mr. Williams noted that SMD is still reacting to uncertainty in Exploration destinations. Dr. Greeley suggested including some acknowledgment of science as guided by the discipline NRC Decadal Surveys. Dr. Huntress felt it would be useful to reiterate how the nation conducts its scientific enterprise, by creating a better statement of SMD's separateness from Exploration, emphasizing that peer review and competition will continue to guide SMD, creating the best science and science missions. Mr. Williams noted that this philosophy is already stated in the Principles section, and asked for specific edits to help strengthen the statement. It was also suggested that the competitive nature of the Decadal Surveys themselves be conveyed.

Mr. Williams reported that the Science Plan now includes a discussion of dissemination of results in open-access journals, modification of some planetary science questions, and the addition of Near-Earth Object (NEO) detection and tracking as mandated by Congress, a table of the current subcommittees, updated challenges to the FY11 budget request, and cost considerations in the Access to Space section. Specific comments from the Science Subcommittees on the Science Chapters have also been incorporated. Dr. Lean noted that the Sun should be better described as the primary source of electromagnetic radiation. A brief discussion ensued on the accuracy of NASA's statement on its unique Earth Sciences integrated research program. Dr. Tapley felt this was a defensible claim, but agreed with other Science Committee members that specific capabilities be listed and verified, in lieu of making a

“rankling” statement.

Mr. Williams reviewed the final steps before publication, and hoped to use the first half of May for review after holding the comment period open until the end of April.

Major science highlights in Earth Science have been incorporated into the Science Plan, including understanding Antarctic “plumbing” and the influence of temperature changes, interactions with aerosols that boost the warming potential of some gases, the decline in Arctic sea ice over time, and detection of groundwater depletion in California and India. Dr. Weiler suggested using a longer data record (back to the 1980s) to show both variation and decline in Arctic sea ice. Dr. Lean suggested mentioning the mandate from Congress to monitor the Earth’s ozone hole, or adding some stratospheric data.

Heliophysics science highlights now include recent observations of magnetic reconnection within the auroras, data on the anatomy of solar coronal mass ejections (CMEs), evidence of the galactic magnetic field shaping the heliosphere from the Interstellar Boundary Explorer (IBEX), and first light data from SDO. Dr. Lean suggested adding data on polar mesospheric clouds, and observation of Shuttle plumes, as well as the current anomalous solar minimum and its effects on the ionosphere/thermosphere/mesosphere.

Planetary science highlights include Cassini’s observations of the plumes on the Saturn satellite, Enceladus, evidence of water on the lunar surface and methane on Mars, and signs of past surface water on Mars. Dr. Weiler suggested adding photos of Mars craters surrounded by ice, and MESSENGER’s first global map of Mercury.

Astrophysics science highlights include the latest HST results, images from the Physics of the Cosmos missions such as Chandra and the Fermi telescope, initial Kepler results on detection of new exoplanets, and detection of methane and carbon dioxide in exoplanetary systems.

Lunch talk

Dr. Compton Tucker presented data on tropical glacier extent variation in the New World, and Dr. Thorston Markus presented recent findings on Arctic sea ice measurements.

Planetary Sciences Subcommittee Update

Dr. Ron Greeley, Chair of the Planetary Sciences Subcommittee (PSS), briefed the Committee on recent activities within PSS, first highlighting the products of its 6 analysis groups. He noted that at the Rayburn Building in Washington, D.C. on July 15, 2010, there will be an exhibit celebrating the 400th anniversary of the discovery of the Galilean satellites; this exhibit will focus on science results from the NASA-ESA Galileo spacecraft, as well as current and future exploration of the Outer Solar System. The European Space Agency (ESA) and NASA have signed a letter of agreement regarding a potential mission to Europa and the Jupiter planetary system (Europa Jupiter System Mission). PSS also put forth a finding supporting the re-initiation of Pu-238 production in the U.S. to support planetary science missions. A finding on the International Mars Program, noting progress towards an international collaboration working toward sample return, was also noted, recognizing the need for the cooperation of science and technology cultures, on both sides of the Atlantic, to reach this goal. Technologists need to understand the science motivation, and scientists need to better appreciate technical limitations.

PSS delivered a finding on uncosted carryover funds. Dr. Greeley observed that Congress seems to recognize that in the case of the National Science Foundation (NSF), for instance, there are legitimate reasons for this carryover, however, to date Congress does not seem to realize that many of these same reasons apply to NASA activities. PSS has therefore recommended that Congress be made aware of the elements at NASA that have similar issues leading to uncosted carryover. Dr. Weiler suggested, as a

means of amelioration, that each university grant officer establish a personal relationship with a contact at NASA to better manage uncosted carryover. A meeting participant commented that a use-or-lose policy could be beneficial in clearing the books. Dr. Weiler added that NASA has tamed the unobligated carryover, but is worried that Congress will next target uncosted carryover. The Science Committee recognized that the community must take pains on educating itself on this issue.

PSS has made a recommendation on a potential collaboration between SMD and ESMD, especially in robotic precursor missions, to formulate a “Humans to Moon, Asteroids and Technology Roadmap” to help guide robotic missions. Such a Roadmap would be beneficial to PSD and ESMD and could use as a basis documents from existing analysis groups.

PSS has also recommended that ESMD and SMD collaborate on the next call at the Lunar Science Institute (LSI) to support and enhance the goals of both directorates. Dr. Weiler reminded the Science Committee (SC) that the LSI was imposed by a different administration; in addition, none of this money for ESMD’s new missions has been appropriated and there is no budget for exploration precursors. Dr. Greeley stated that PSS was merely trying to prioritize science through this recommendation, where there is mutual interest. Dr. Weiler felt that the Decadal Survey’s South Aitken Basin proposal was the only appropriate project for SMD, since it is the only one that had been competitively peer-reviewed. Dr. Levy commented that where there are accepted science objectives, the community ought to respond with alacrity, but supported Dr. Weiler’s objections; he felt that the lunar objective had distorted the science issue, and that the SC’s role was to reframe priorities in a rational fashion.

PSS has recommended that the Lunar Exploration Roadmap (LER) be used to guide relevant science issues, and sought guidance from the Science Committee on what PSS should do next in the context of LER. Dr. Huntress felt that by the Summer/early Fall, there would probably be some clarification of exploration plans, and requested that Dr. Greeley hold the recommendation on LER until the next meeting.

PSD Science Highlights

Science highlights in the Planetary Science Division include recent LRO images of impact melts on the lunar surface, flow-like structures that are not volcanic in origin; the total volume of flow material is substantially more than models would predict and has engendered a reassessment of models. Mars water is also being seen at latitudes closer to the equator, particularly in fresh impact craters that expose water ice. MRO’s shallow radar instrument, SHARAD, has also provided evidence of glacial ice that is buried beneath the surface. More data are being accrued on asteroid processes and diversity, including evidence of asteroid collision; meteorites from a recent collision have been found to be a combination of stony, primitive and processed objects. These recent events suggest that asteroids can be heterogeneous, and that a single spectral classification may not be appropriate for their classification. Reaccretion of asteroids may occur. Evidence of volcanism on Venus has been obtained from high emissivity signals, suggesting ferric minerals such as fresh basalts- these minerals would have to be young as they would weather quickly in the Venusian atmosphere.

Dr. James Green, Director of PSD, continued the presentation, citing a recent result from Mars Express that suggests solar wind contributes to the loss of Mars atmosphere. Other observations include the result of impact events that trigger avalanches on Mars. In a terrestrial use of Mars technology, the MSL ChemMin instrument is being leveraged by the Centers for Disease Control (CDC) for application to a malarial drug verification technique. Surface differences between Ganymede and Callisto have been noted, suggesting that one satellite has resurfaced itself more frequently over time, perhaps due to impact events. Recent Cassini images have revealed a giant “footprint” of methane or ethane lakes on Titan, analogous to terrestrial lakes and bays.

Dr. Green reported that the PSD FY10 budget ended up with a general reduction of \$18.2M; these reductions were allocated based on principles previously devised by PSD. The reductions took \$4M out of Discovery, \$3M from R&A (due to uncosted funds) and \$11.2M from LADEE. PSS agreed with the approach taken. PSD anticipates several civil servant Program Scientist opportunities at Headquarters this year. The Discovery AO is scheduled for release in June, with proposals due before end of calendar year (CY) 2010. PSD has also received proposals for instruments on ESA's Trace Gas Orbiter for the Mars 2016 opportunity, with selection to be announced by the end of this fiscal year. There will be no funding available for missions of opportunity (MOOs) this year. After GRAIL, Juno, and MSL are launched next year, PSD will attempt to apportion funds for a MOO.

In international proceedings, NASA and the China National Space Administration (CNSA) held a bilateral meeting which focused on persuading China to agree to open data policy. NASA has invited CNSA to participate in Lunar Science Institute (LSI) and International Lunar Network (ILN) activities. NASA and ESA have assembled various joint science teams for future Mars opportunities.

Status of Pu-238

Administrator Bolden recently signed a letter to the Department of Energy's Secretary Chu, updating NASA's estimated need for Pu-238; however, funding to restart domestic production still needs to be approved by Congress as part of the FY2011 Appropriations process. The new Pu-238 requirements are lower than what had been anticipated for human exploration missions to the lunar surface under the Vision for Space Exploration; this new estimate will be reflected in the updated Department of Energy Pu-238 restart plan. Dr. Weiler remarked that the early restart of domestic Pu-238 production remains crucial, as the Pu-238 must be "cured" for three years to allow adequate dissipation of dangerous gamma radiation before it can be processed into a usable form.

Dr. Green noted that the Planetary Supporting Research and Technology (SR&T) program has been brought back into budgetary alignment with 2004 levels, and recognized that instrument development activities could use a boost/rearrangement in funding to support higher-TRL instruments. PSD has also analyzed money spent on objects in the solar system. PSS is establishing a working group to support an SR&T review.

Earth Science Subcommittee Update

Dr. Byron Tapley, chair of the Earth Science Subcommittee (ESS) reviewed science highlights of the ESD, most recently the employment of A-Train satellites to view Iceland's volcanic eruption, primarily via Aqua's and Aura's MODIS and OMI instruments, which provided detailed characterization of the ash cloud. The Ozone Monitoring Instrument (OMI) aboard EOS-Aura and the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard EOS-Aqua fly in formation as part of the A-train.

Dr. Tapley reviewed subjects considered in the March 2010 ESS meeting, including initial planning for a highly constrained budget. ESS has since been assured that Decadal Survey Tier 1 missions are in a healthy state of development (CLARREO; Soil Moisture Active and Passive, ICESat II, and Deformation, Ecosystem Structure and Dynamics of Ice missions) and that foundational and Congressionally directed "national needs" missions (DSCOVR, SAGE-III and GIFTS) now have support from a Congressional augmentation that was directed at ESD earlier this year. The NPOESS issue remains a topic of concern and is an ongoing activity. While the overall picture has greatly improved, ESS remains concerned with continuity of measurements and simultaneity due to the aging of orbital assets, continuing dialogue with the international community, data disparities, uneven application of open-skies policies, and interagency collaboration supporting NPOESS/JPSS, and the potential for an integrated Earth-observation system. A

major focus for the future will be details of FY11 budget request, as well as the ESD Science Plan. The subcommittee has not formally discussed ISS utilization, which is an ongoing topic for consideration.

Earth Sciences Division Update

Dr. Michael Freilich updated the Science Committee on ESD's FY11 \$2.4B augmentation, and provided the Committee with the budget allocation in terms of the year 2000 budget. The division has submitted a plan to the Office of Management and Budget (OMB) and the Office of Science and Technology Policy (OSTP) detailing how the funding augmentation would be allocated. Programs (foundational missions) that are already on track will not have new monies applied to them. The foundational missions, which were on hold 3 years earlier, are now moving toward realistic launch dates. Dr. Freilich noted that once NPP launches, it will become a national meteorological asset.

The augmentation has allowed ESD to move ahead rapidly on the Orbiting Carbon Observatory (OCO-2), which will be launched on a fast track for 2013. The augmentation also allows launch of all four Tier 1 missions between 2014 and 2017, meeting simultaneity requirements, and expanding and accelerating the competitive, PI-led Venture-class program. This funding will further develop selected Climate Continuity missions such as the Stratospheric Aerosol and Gas Experiment (SAGE-III), the Gravity Recovery and Climate Experiment (GRACE) follow-on, and potential additional measurements identified with the United States Global Change Research Program (USGCRP). It will also enable key non-flight activities such as a multi-year carbon monitoring pilot program, expanded modeling, synthesis and computing ability, and expanded geodetic ground network. In addition, with USGCRP, ESD will be identifying and enabling additional Tier-2 missions.

Operating mission status

ESD currently has 13 satellites in operation; 9 satellites are supported by significant international collaborations. ESD is greatly increasing collaborations with ESA and is scheduled to sign an international framework for field campaigns, ground systems, development of combined data products, mission interoperability, and flight missions. This agreement has been greatly facilitated by ESA's decision to join an open-data policy, which will be retroactive. ESD is also collaborating with the Japan Aerospace Exploration Agency (JAXA) on three major initiatives, including a formal agreement to return data from the ALOS satellite through NASA's TDRSS, effectively doubling to tripling the bandwidth of the mission. Collaboration is also under way between JAXA carbon science teams, and GPM. ESD is also collaborating with the French space agency CNES on the SWOT mission (wide swath altimetry for hydrology and oceans), and work package divisions associated with this mission. NASA is also having sustained discussions with the Brazilian space agency INPE on a Global Precipitation Mission (GPM) collaboration, with NASA providing the GMI-2 instrument, accommodation costs and data downlink, and INPE providing spacecraft and launch services. Germany has agreed to provide GRACE funding through the end of mission, and is discussing the GRACE follow-on with NASA. The Argentinean agency CONAE is collaborating with NASA on Aquarius, with NASA providing instrument and launch, and CONAE providing the spacecraft and 7 instruments.

GLOPAC, an atmospheric chemistry and dynamics experiment, is using a Global Hawk high-altitude unmanned aerial vehicle (UAV) to study trace gases in the troposphere and stratosphere, including fragments of the polar gyre that are migrating to lower latitudes. GLOPAC has made 2 flights thus far, taking vertical profiles of the atmosphere, and confirming that UAV fuel functions properly at very low temperatures. In September, ESD plans to fly the Global Hawks over hurricanes, gaining hours of loiter time over the storms. The next Venture-class AO will incorporate small satellites in late 2011, and the first of an annual set of calls for major ES instruments (\$90M) will be held in 2012.

NASA's Technology Initiative

Dr. Robert Braun, NASA Chief Technologist, presented details of the Agency's recently established Office of the Chief Technologist, first providing some history underlying the impetus for the program. The President's FY11 budget request reflects a heavy emphasis on technology; in addition, for several years, external input from committees, the National Research Council (NRC) and Congress have called for technology development in various forms within NASA, often focusing on the importance of advanced concepts. Drawing on his history in formulating Mars Pathfinder, Dr. Braun noted that this mission had been a game-changer, in that it generated new interest in the exploration of Mars, hence influencing a long series of Mars missions. Dr. Braun also cited Mars microprobe technology development, which helped to support the development of a single-stage atmospheric entry system that is now being considered for Mars Sample Return as an example of success from a "failed" program. He also discussed how technology investments made by ESMD in preparation for development of Orion's thermal protection system, greatly assisted MSL in raising the technology readiness level of the tiled Phenolic Impregnated Carbon Ablator (PICA) heat shield system, which was ultimately selected for flight on the MSL mission. This effort also led to arc jet testing as an indispensable thermal protection system (TPS) tool.

A considerable technology investment will be required for a human Mars mission; it will take about 12 ISS masses in low-Earth orbit (LEO) to initiate one round-trip human Mars mission. Technology development needs to reach a two-mass capacity before one can even begin the discussion for a human Mars mission.

The roles and responsibilities of the Chief Technologist are to function as a principal advisor and advocate to the Administrator; provide communications and up-and-out advocacy for NASA research and technology programs; direct management of the OCT Space Technology program; coordinate technology investments across the agency; and support a portfolio of technology investments enabling NASA to pursue entirely new missions of exploration and discovery. The approach will be to prove the fundamental physics of a particular technology first, followed by a technology demonstration in the relevant environment. OCT will combine ESMD technology pull (propulsion, e.g.) and Space Technology Program technology push, and is seeking disruptive approaches. The effort is to be composed of early stage innovation and foundational research, followed by a steady cadence of technology demonstrations, as well as early investment in long-lead capabilities which will be needed for future deep space and surface exploration missions. Asked about plans for heavy lift options, Dr. Braun replied that while OCT is evaluating options at present, such as aluminum vs. composite tanks), there are no new radical options.

Ideas for technology development within OCT will arise from competition such as requests for proposals, Broad Agency Announcements, AOs, some targeted subjects, and some broader, grand challenges in communication or propulsion. The purpose of OCT will be to advance non-mission focused technology and broadly applicable technology that is of use to multiple customers. Examples of crosscutting technologies may include lightweight structures and materials, advanced in-space propulsion, nano-propellants, lightweight large-aperture space systems, energy storage systems, high-bandwidth communications, inflatable aerodynamic decelerators, and power generation and transmission systems. The office has three divisions: Early Stage Innovation, Game-Changing Technology, and Crosscutting Capability Demonstration. Under the Crosscutting Technology Demonstration division, a new version of the New Millennium program is essentially being stood up. Roadmaps are currently under way to guide these activities, such as for Aerocapture, and Entry, Descent and Landing (EDL) Technology. A renewed emphasis on technology can support NASA as a catalyst for innovation and economic expansion in the U.S., provide support and a pipeline for young talent in the Science, Technology, Engineering and Mathematics (STEM) disciplines, and meet broader national needs in energy, weather, health and

wellness, Earth science, and national security.

Asked how OCT would interface with SMD, Dr. Braun explained that the NASA Technology Executive Council will be the vehicle for integrating the Space Technology program with SMD. The council will include representation from SMD, and will meet regularly and work to resolve discrepancies, reduce redundant efforts, etc. Dr. Braun felt there would be little chance of a Technology Directorate being formed, noting that each directorate has been doing a good job in its own area; the missing portion has been the cross-cutting technologies. As for international collaboration, International Trafficking in Arms Regulations (ITAR) remains an obstacle and is being revisited by the Administration. OCT will have to learn to work with restrictions, especially with intellectual property (IP). Corporate IP will also be an issue. OCT plans to deal with the issue by calling for teams and thereby incentivizing collective work. Some concrete metrics for OCT are in development, such as the number of ideas that make it to fruition (long-term); how many crosscutting capability demos get into future NASA missions, and so-called "failure" metrics. Dr. Braun welcomed competition in open calls in what he thought of as Discovery-class calls that anyone can propose to, and that are graded on the potential for technology advancement instead of science value.

Q&A with SMD AA

Dr. Weiler reviewed notable SMD events of the last two months. SMD staff has spent a fair amount of time briefing Congress, including the Senate and House Authorization Committees. Dr. Weiler reported that the briefings were characterized by a good exchange of information and little negativity. SMD is also busily communicating with newly established non-SMD programs, such as OCT's Space Technology Program. The directorate has held bilateral meetings with ESA, and has recently agreed to meet semiannually to continue to define cooperative missions. SMD has established a new Joint Agency Satellite Development office to manage the JPSS mission for NOAA, with eleven new billets, some of which are spread out in support and budget offices. Dr. Lean asked which agency would analyze data records for JPSS. Dr. Freilich responded that while data analysis is a NOAA role, ESD may decide to put resources into it. There will be science input from NASA in a formal way, which can be passed to NOAA and negotiated. The data analysis and stewardship would reside at Goddard Space Flight Center, according to the draft structure.

SMD has received the NRC report on Revitalizing NASA's Suborbital Science Program, and continues to work with OMB/OSTP and DOE on the Pu-238 issue. Dr. Weiler felt that the Pu-238 issue may actually be resolved. SMD is still in the process of responding to President Obama's re-vectoring speech at the Kennedy Space Center, and must continue to weigh the potential effects of a Continuing Resolution, should the FY2011 budget not be approved before the start of the fiscal year. Asked about the role of the Chief Scientist, Dr. Weiler replied that it would be a staff position, without resources for building and launching programs. The primary role of the Chief Scientist would be up and out be as a spokesperson for NASA. NASA is seeking a respected senior researcher/faculty member, a functional analog to the Chief Engineer. A Chief Scientist could revitalize life sciences/microgravity on ISS, a community that had largely disappeared in recent years. Dr. Huntress agreed that this entire community must be reconstituted.

April 21, 2010

Astrophysics Update

Dr. John Morse, Director of the Astrophysics Division (APD) briefly reviewed the administrative status of the Astrophysics Subcommittee (APS). Dr. Morse welcomed new members to the APS, including incoming Chair Dr. Alan Boss, as well as newly sitting members Drs. Lou Allamandola, Mary Beth Kaiser, Vicky Kalogera, and Steve Ritz.

APD Science Results

Dr. Boss presented the latest science results from the APD. HST detected a brown dwarf star with a planetary mass companion of 5-10 Jupiter masses, with a Saturn-like orbit in distance. Herschel's HIFI instrument detected a spectrum of water and organics in the Orion nebula, including dimethyl ether, methanol, CO, and SO₂, indicators of life's precursor molecules. Spitzer warm phase imagers have turned to a search for time variability of young stars in Orion, following 1500 young stars over a time series in the hope to see evidence of rotating disks, etc. The Fermi (formerly GLAST) telescope, in studies of the radio galaxy Centaurus A, has managed to resolve gamma rays correlating with known radiofrequency emissions. Dr. Burns viewed the Fermi results as spectacular and model-transforming. The Wide-field Infrared Survey Explorer (WISE) detected interesting chemical processes in the Berkeley 59 cluster in the Cepheus region, where a supernova remnant lies, constituting what might be a Solar System analog, triggered by a supernova shockwave.

Dr. Morse resumed the presentation, highlighting recent programmatic events. JWST passed CDR at the mission level last week, and will undergo a programmatic review in May. HST celebrates its 20th birthday in 2010. APS is working on a response to the NRC study of NASA's suborbital research capabilities. The study has recommended an extended duration sounding rocket, short duration experiments, ultra long duration balloon capability (100 day campaigns at mid-latitudes), and campaigns at both polar regions. A Senior Review of operating missions was held in early April, covering 11 missions: RXTE, Suzaku, Spitzer, Chandra, WISE, Planck, XMM-Newton, INTEGRAL, GALEX, WMAP, and Swift. A final report will be delivered by late April. WMAP will be terminated. Dr. Lean asked if terminated missions could be revived. Dr. Morse felt this to be unlikely, as the budget is heavily oversubscribed. He did note, U.S. scientists can still write proposals to international missions.

The Astronomy and Astrophysics Decadal Survey (Astro 2010) is expected to be released in September 2010. APD has sent a letter to Astro 2010 committee describing potential partnerships on ESA's Cosmic Vision M-class mission candidates, including Euclid (dark energy mission) and PLATO (exoplanet mission). Contributions of up to 20% of the total mission value to ESA can be made through a NASA-sponsored instrument AO, providing hardware to spacecraft or ground/launch segments, or U.S. participation on ESA teams. All data from these efforts would be archived and made accessible after proprietary periods (i.e. primary mission phase, usually one year). The data policy would be determined by peer review. In the meantime, NASA has dispatched two scientists per mission to evaluate science payloads, and engineers to examine technical aspects of the ESA missions. NASA will receive the Decadal Survey results before committing to Euclid or PLATO. JDEM, Space Interferometry Mission (SIM) and related efforts will continue this year, pending Decadal Survey results. Scientific priorities that are not highly ranked will not be pursued. Dr. Morse noted that JDEM and SIM currently have no budget in FY11. Dr. Weiler interjected that APD is trying to give the Decadal Survey realistic options, given the European initiative in dark energy. Dr. Morse added that launch of JWST must occur before a significant budget wedge opens up for new missions in APD; this has been communicated to Astro 2010. The division is now spending ~ 40% of its budget on JWST and has a much more balanced program at present.

Kepler data release policy

During the APS meeting addressing this issue, Dr. Boss recused himself from the discussion, and Dr. John Huchra acted as APS chair in addressing the Kepler data release issue. Dr. Huchra described the issue: The Kepler science team has requested a revision of Kepler data release. Guiding principles for data release include fairness to the team, interest in assuring high-quality data (data verification), and a desire on the part of NASA and the community to release data in a timely manner. Astro 2010 is expected to make specific recommendations regarding exoplanets, which are currently a topic of high interest. APS disagreed strongly that the proprietary period for Kepler results be extended, as this would set a bad

precedent and reduce scientific output. APS ultimately recommended, in a non-consensus decision, that a compromise Option #3 be adopted as a means of retaining the original intent of the Kepler agreement; it preserves the letter of original agreement to have one observing season to confirm interesting targets. Option 3: Data for majority of Kepler target stars released according to baseline schedule, with science teams allowed to extend the proprietary period during a limited number of defined periods per quarter. Dr. Huchra commented that because there is no way to absolutely rule out false positives, it is not worthwhile to sequester data for an extended period. Dr. Burns supported the APS conclusion and the Science Committee concurred. Dr. Huntress agreed to include this concurrence as a finding for the committee.

Dr. Huntress asked Dr. Morse if APD had considered ISS utilization. Dr. Morse explained that ISS utilization is already allowed in ROSES. APD is also in the process of selecting scientists to participate in the development of a JAXA instrument for ISS. Proposals for ISS payloads were received as partner Missions of Opportunity (MO) in response to the Small Explorers and MO 2007 solicitation. The only MO selected was the Astro-H mission, which is not an ISS mission. Dr. Weiler recommended that proposal pressure determine the extent of science involvement in the ISS. Dr. Burns felt that ISS utilization principles should be resolved at the Science Committee level, pending individual Science Subcommittee discussion results.

Heliophysics Update

Dr. Roy Torbert, Chair of the Heliophysics Subcommittee (HPS), reviewed Heliophysics science highlights. Recent data has been acquired on the origins of solar energetic particles (SEPs) helping to better understand this hazard for manned spaceflight and satellite. Observations from three missions have revealed new data on compositional variability (ratio of Fe to O) of SEPs relating to the solar region that produced the particles (active region or coronal hole), and have identified a new input for models to help predict the severity of the SEP radiation hazard.

Participants at the Yosemite Reconnection Conference presented a suggestion, in a new simulation by Daughton *et al.*, that reconnection may be explained by the geometry of “islands” on the solar surface, a possible solution to the riddle of reconnection. If confirmed by Magnetospheric Multiscale (MMS) mission observations, these findings would represent a major step forward.

Dr. Torbert reviewed HPS findings from the subcommittee’s latest meeting. Notably, great concern had been expressed about the loss of the HPD Guest Investigator program and its negative impact on the Great Observatory (GO). Joe Bredekamp noted that HPD shares the concern and will make every effort in the formulation of the FY 12 budget submission, as well as in the potential execution of the FY 11 budget to mitigate this consequence. Dr. Paul Hertz added that the cuts to the GI program resulted from a direct Congressional action. HPS also registered a finding on budget constraints, noting a significant hit to each mission line for detailed orbital conjunction analysis (collision avoidance). As a result, SMD has decided to review the requirements on a division-by-division basis, to be followed by an SMD-wide response. HPS also stated its strong endorsement of frequent launch opportunities offered by the Explorer program. Dr. Feeley reminded the Science Committee of its previous recommendation to allow the AA maximum flexibility in making a decision on the Explorer AO.

HPD Status

Mr. Joe Bredekamp presented the HPD status, standing in for Director Dr. Richard Fisher, beginning with recent mission events, the most prominent being the successful launch of the Solar Dynamics Observatory. All the instruments are now turned on and performing well, and the First Light Press Briefing held later on April 21, 2010, is expected to generate exciting prospects for the science produced by this mission. The other mission under development in the Living with a Star (LWS) Program,

Radiation Belt Storm Probes (RBSP) continues to progress. BARREL, a balloon under flight campaign for RBSP, completed both a Preliminary Design Review (PDR) and Confirmation Assessment in March. Also within LWS a Solar Probe Plus mission was approved for formulation and a Phase A contract is expected to be awarded by April 30, 2010. The Magnetic Multi-scale (MMS) mission under development in the Solar Terrestrial Probe program continues to progress heading to the Critical Design Review (CDR) this summer.

A potential partnership with ESA on the Solar Orbiter candidate mission is being considered for selection under their Cosmic Vision program. The four NASA-provided instruments have reviewed accommodations/interface requirements with ESA/Astrium and a meeting will be held in June to confirm the Solar Orbiter Payload Complement Programmatic Readiness.

The HP Great Observatory fleet of 16 operating missions with a total of 27 spacecraft is expected to soon add SDO to the complement. The biannual Senior Review of those operating missions is being held this week to consider proposals for extending the missions based on science merit and value. The Panel faces some serious deliberations in view of the tight constraints on budgets.

In the Sounding Rocket Program managed by HPD for SMD, an issue with the Black Brant Thrust Termination Systems necessitates an upgrade and inventory resupply, which in turn will require re-planning the summer schedule. HPD is also working the response to the recently-delivered NRC Suborbital Study report.

Mr. Bredekamp then provided two additional HPD science highlights. The first was observation of an eruptive prominence on the limb of the Sun as a result of the largest coronal mass ejection event seen in several years, as viewed from 3 spacecraft (Stereos A and B, and Solar and Heliophysics Observatory (SOHO)). This offers key insight into the three dimensional nature of the magnetic field expansion into the solar system. Mr. Bredekamp also displayed a sneak preview of one of the SDO composite images to be released that afternoon at the First Light Press Briefing. This preliminary 3-color composite of a small active region near the west limb of the Sun gives a sense of the unprecedented spatial, temporal, magnetic field, surface tomography, and temperature resolution, and the potential to vastly change our understanding of the Sun and its processes.

In response to a prior request, Mr. Bredekamp reviewed the SDO life cycle cost trace, from pre-formulation to the current estimate. Since Confirmation in May, 2004 there has been a total increase of 9.4% in cost and 22-month slip in schedule attributable to a number of factors, including a 14-month delay waiting for a place on the Atlas-V launch vehicle manifest. Dr. Lean asserted that SDO had in fact grown by a factor of three over initial estimates given to the Science Definition Team, and that these increases must be viewed as a true "cost of doing business." Dr. Huntress commented that missions need to identify cost categories in the pre-formulation phase, and spend enough money in pre-Phase A and Phase A to better articulate cost expectations.

Lessons Learned from the New Millennium Program

Dr. Ray Taylor presented a summary of lessons learned in the former New Millennium Program (NMP), based on materials derived from a formal assessment performed by JPL. NMP's original role had been to advance low-TRL (technology readiness level) technologies through flight validation in space, or from TRL-1 to TRL-7 (prototype demonstration in a space environment) or TRL-9 (actual system flight proven through successful mission operations). Through its lifetime, NMP validated a significant number of technologies, one of which is still in progress (ST-7 micronewton thrusters for the LISA-Pathfinder mission). Five of six projects flown during NMP met their full mission criteria for success, and nearly all technologies flown were validated to TRL-7. Eight projects were terminated for cost growth/maturity

issues. NMP's technology review boards, independent of the projects, were considered key in ensuring the validity of NMP achievements.

Counted among NMP successes were: an increased ability to assure reliable access to high-science value areas, miniaturization of instruments, and the ability to send more science payload masses to planetary bodies with atmospheres. Examples include Deep Space 1 ion thrusters, which were employed on the Dawn mission, as well as transponders from the same project that were used on Dawn, the Mars Exploration Rovers, and MRO. Constellation operations from ST-5 helped to enhance SDO, GLAST and LRO.

Access to space presented a major impediment to progress in NMP. In particular, partnering with the Air Force was viewed as having caused programmatic risk through a multiyear slip. Dr. Taylor noted that ESPA (vehicle-modifiers for payloads) rings could mitigate this risk in the future, expanding access to other rockets. Dedicated missions for subsystem validations within NMP were also considered too expensive, in addition to the programmatic constraint inherent in only addressing technologies which require validation on-orbit.

In summary, NMP demonstrated the benefit of advancing technologies to TRL 6-7 levels. Dr. Huntress remarked that there is still a need to validate technologies outside of the OCT office, and asked whether SMD would have access to OCT to validate technologies. Dr. Taylor reported that SMD now has an interface (Michael Moore) with OCT, and that connections are continuing to be made. He added that potentially large investments in ESMD will also be made, and that concepts and issues will also be reflected in the new Technology Roadmap. SMD may be able to leverage other efforts besides OCT. Mr. Moore said he hoped to have a more crisp presentation of these developing relationships by the next meeting of the Science Committee. Dr. Burns asked if there were a way to connect the OCT more closely with the Explorer program. Dr. Torbert commented that Explorer was insufficiently risk-tolerant for technology development efforts. Dr. Huntress observed that NMP suffered from the conflicting requirements between science and technology. Mr. Moore noted that OCT will wrestle with science vs. technology requirements in the Technology Roadmap, recognizing that NASA technologies tend to have to be pushed. He also noted that a coherent set of needs and requirements must be constructed, which also must meet the multiple applicability requirements of OCT. ISS as a TRL test bed was considered to be too costly.

ISS Utilization

Mr. Mark Uhran presented a briefing on the continuing utilization of the International Space Station (ISS). Because the President has proposed to extend ISS lifetime beyond 2015, SOMD is looking at ways to extend its lifetime beyond 2020. ISS utility, however, must first be thoroughly characterized before a final lifetime is determined. A total of \$70B has been invested globally as ISS enters the next decade of utilization. STEM education is also increasingly part of the ISS program. There are roughly 34 international payload racks (23 U.S. payload racks) distributed across ISS. Station-wide, there are on the order of 50-60 payload sites, and each site can accommodate a variety of experiments. Overall, there is capacity for several hundred payloads on the facility. Using external sites such as Express Logistic Carriers (ELCs; 9800 lbs capacity) and the JEM Exposed Facility (5500 lbs and a 1.5m³ volume capacity), the ISS is designed so that payloads can be turned over on a regular basis.

There are a variety of ISS nodes available for docking. The ISS program is working to make these docking ports completely interchangeable so that any country's vehicle can dock at one of them. The capacity as a test bed is ISS's most valuable characteristic; it is essentially a deployed permanent bus, is resupplied on a quarterly basis, and is continually crewed. ISS can accommodate class D hardware, and as mission success criteria are less stringent than for most missions at NASA, ISS projects tend to be less

costly as well. Russia's Soyuz vehicle is viewed as the crew taxi, and the Progress vehicle as the hauling truck. NASA has committed to the Russians through 2012 for these capabilities. In the meantime, the European ATV and Japanese HTV have each made a successful maiden flight to ISS, while the U.S. companies Space X and Orbital Sciences have yet to make their first vehicle demonstration flights. Currently, the only vehicle with appreciable downmass capability (~ 3.0 metric tons) is the Dragon, and Soyuz has only minimal (~ 75 kilograms) downmass capability.

SOMD is fully budgeted for cargo resupply through 2015. Hence, transportation to the ISS is paid for or bartered on transfer vehicles, and is contracted as an annual service. SOMD is the primary contact for flight opportunities or proposal development. Mr. Uhran recommended himself or Paul Hertz as contacts for interested parties. The ISS budget allows for an additional 3 metric tons per year, beyond the requirements for upmass to maintain the Station and carry out the NASA research program. Responding to a question, Mr. Uhran maintained that manifesting is the same challenging process it has always been.

ISS is a platform for Earth observation, from which one can see 75% of the world's land surface. It is not an ideal platform for some viewing purposes, due to low frequency jitter, however environments are well defined and under continual evaluation. ISS can capture changes on Earth's surface, such as thinning ice in Siberia. It can also be used as a platform for astronomical observation. At present a "Top 100 NASA Ideas" for technology demos on ISS is in the process of downselection. Mr. Uhran displayed a brief animation of the ISS and its environment.

Mr. Uhran briefly reviewed elements of the micrometeoroid/meteor and orbital debris (MM&OD) system that helps to shield ISS elements from space debris, explaining that the program also receives information from other orbiting assets to avoid collisions. Dr. Lean asked about ISS overhead costs associated with its human rating. Mr. Uhran replied that the program has tried to make overhead less onerous through standardization, and has improved the safety certification process, but allowed that human-rated costs were still a challenge. Proposed experiments bear the cost of the safety certification. ISS has briefed OMB and is preparing to brief Congress on NASA plans to pursue an external nonprofit management structure for non-NASA uses of the ISS; NASA will continue to manage its own missions in-house. NASA uses about 50% of the ISS capacity, and most of the non-NASA interest to date exists on the interior of the facility. ISS now needs to plan on how to reserve capacity on the exterior. Mr. Uhran cited an excellent ISS success story in which microgravity experiments on methicillin-resistant *Staphylococcus aureus* (MRSA) led to the creation of a target vaccine against MRSA, a major cause of mortality and morbidity in U.S. healthcare facilities. Orbital effects on cell culture and genomic expression also has implications for plant cultivars and astrobiological philosophy.

Asked about logistics for carriers to the ISS, Mr. Uhran noted that a move from Space Shuttle usage to a commercial supplier within 12 months would be ideal. There are current opportunities on the Japanese vehicle, and Europe is also lined up to provide cargo delivery services on its vehicle.

Discussion

The committee discussed action items for each subcommittee, particularly for compilation of science that can be performed on ISS, including estimated costs. Dr. Greeley referred to previous brainstorming sessions on microgravity, which also dealt with maturation of technologies and development of sample acquisition and handling techniques for the asteroid environment. Planetary protection is also an issue for sterilization of components in space. Dr. Tapley felt that for Earth Science, an altimeter on ISS might be helpful for niche experiments. Dr. Torbert noted that ISS did not fly in an especially attractive orbit for Heliophysics. Dr. Hertz reminded committee members that information on ISS costs, environment, and logistics is available in the AOs, on the web; these data are already available in the upcoming Explorer AO, and other relevant information resides with the Executive Secretary of each Science Subcommittee.

The Science Committee took time out to watch the first-light press conference for SDO.

Public comment period

No comments were noted.

Findings and recommendations

The committee discussed various findings. There was concurrence on taking the Pu-238 issue to the level of the NAC. A finding on the International Mars program was directed to SMD. The concern over uncosted carryover was deferred to the general community. A finding on a lunar sciences proposal was conveyed to Dr. Green. A recommendation about robotic precursor Roadmap collaborations was raised to the level of the NAC. Dr. Braun supported a finding on endorsement of the OCT and flight technology program to be taken to the NAC; Dr. Weiler suggested emphasizing the importance of peer review in this potential finding. An APS finding on Kepler data policy was reviewed and approved for consideration by the NAC.

The committee considered, and approved, an invitation to Dr. Ron Sega, the Chair of the Space Studies Board (SSB) study on cost growth in NASA's Earth and Space Science missions, to attend the next meeting and brief the committee on the NRC study.

Dr. Huntress suggested that the cut in the HPD Guest Investigator program should be dealt with at the community level and through appropriate interaction with the relevant Congressional staff. He added that the committee could direct the finding at SMD, but that one could not expect an outcome from that finding.

The agenda for the next meeting was to include discussion on costs based on SSB reports, ISS utilization based on Subcommittee reports, a ESMD briefing on Exploration-Science cooperation; a discussion of the Congressional budget pass back (assuming it has occurred in the interim), and a briefing from Mr. Michael Moore on SMD interaction with the OCT.

Dr. Huntress thanked Dr. Weiler for his time spent with the SC, and adjourned the meeting.

Appendix A Attendees

NAC Science Committee members

Wesley Huntress, Carnegie Institute, *Chair*

Byron Tapley, University of Texas, *Vice Chair* and Chair Earth Science Subcommittee

Jack Burns, University of Colorado

Ronald Greeley, Arizona State University, Chair Planetary Sciences Subcommittee

Judith Lean, Naval Research Laboratory

Eugene Levy, Rice University, Chair Planetary Protection Subcommittee

Roy B. Torbert, University of New Hampshire, Chair Heliophysics Subcommittee

T. Jens Feeley, NASA Headquarters, *Executive Secretary*

NASA Attendees

Marcus Allen, NASA Headquarters

Padi Boyd, NASA Goddard

Joe Bredekamp, NASA Headquarters

Janice Buckner, NASA Headquarters

Orlando Figueroa, NASA Goddard

Michael Freilich, NASA Headquarters

James Green, NASA Headquarters

Hashima Hasan, NASA Headquarters

Debbie Hollebeke, NASA Goddard

Paul Hertz, NASA Headquarters

Tibor Kremic, NASA Glenn

Tony Lawson, NASA Goddard

David Leisawitz, NASA Headquarters

Jon Morse, NASA Headquarters

Marian Norris, NASA Headquarters

Douglas McCuiston, NASA Headquarters

Thomas Moore, NASA Goddard

Michael Moore, NASA Headquarters

Charles Norton, NASA JPL

Bill Oegerle, NASA Goddard

Sue Pierpoint, NASA Headquarters

Rita Sawbruna, NASA Goddard

James Slavin, NASA Goddard

Ray Taylor, NASA Headquarters

Harley Thronson, NASA Goddard

Mark Urran, NASA Headquarters

Azita Valinia, NASA Goddard

Lelia Vann, NASA Langley

Ed Weiler, NASA Headquarters

Amy Walton, NASA Headquarters

Nicholas White, NASA Goddard

Greg Williams, NASA Headquarters

Dot Zukar, NASA Goddard

Non-NASA Attendees

Alan Boss, Carnegie Institution, Chair Astrophysics Subcommittee

Randall Correll, Ball Aerospace

Eric Hand, Nature

Garrett Saito, Lewis Burke Associates

Ana Wilson, Harris Corporation

Joan Zimmermann, Harris Corporation

Appendix B
NAC Science Committee Membership

Wesley T. Huntress, Chair
Emeritus
Geophysical Laboratory
Carnegie Institution of Washington

T. Jens Feeley, Executive Secretary
Science Mission Directorate
NASA Headquarters, Washington, D.C.

Alan P. Boss (pending)
Department of Terrestrial Magnetism
Carnegie Institution of Washington

Jack O. Burns
Center for Astrophysics and Space Astronomy
University of Colorado, Boulder

Ronald Greeley
School of Earth and Space Exploration
Arizona State University

Noel W. Hinners
Consultant

Charles F. Kennel
Chair, Space Studies Board
Scripps Institute of Oceanography
University of California, San Diego

Judith Lean
Senior Scientist, Sun-Earth System
Naval Research Laboratory

Eugene H. Levy
Professor and Provost, Physics and Astronomy
Rice University

Byron Tapley, Vice Chair
Director, Center for Space Research
University of Texas, Austin

Roy B. Torbert
Space Science Center
University of New Hampshire

Michael S. Turner
Kavli Institute for Cosmological Physics
University of Chicago

Appendix C Presentations

1. *Goddard Space Flight Center Presentation to the NAC Science Committee*, Rob Strain
2. *Investments in the Future: NASA's Technology Program*, Robert Braun
3. *Astrophysics Subcommittee Summary Presented to the Science Committee of the NAC*, Alan Boss, John Huchra, Jon Morse
4. *Heliophysics Status Update to NAC Science Committee*, Joe Bredekamp
5. *Heliophysics Subcommittee Report to the NAC Science Committee*, Roy Torbert
6. *Update on the SMD Science Plan*, Greg Williams
7. *ISS Utilization, Earth and Space Opportunities*, Mark Uhran
8. *Earth Science Division Update*, Mike Freilich
9. *Planetary Science Division Program Status*, James Green
10. *Planetary Sciences Subcommittee Presentation to the NAC Science Committee*, Ron Greeley and James Green
11. *NAC Science Committee: Earth Science*, Byron Tapley
12. *New Millennium Program*, Ray Taylor
13. *Tropical Glacier Extent Variation in the New World*, Compton Tucker

Appendix D

**NAC Science Committee
April 20-21, 2010
GSFC, Building 1, Room E100**

Agenda

Day 1 (Tuesday, April 20)

8:30-8:40am	Remarks and Announcements	Huntress, Feeley
8:40-8:50am	Center Welcome	Strain/Figueroa
8:50-10:00am	GSFC Overview	Strain/Figueroa
10:00-10:15am	Break	
10:15-11:00am	Science Plan	Williams
11:00-11:45am	Discussion	
11:45-12:45	Working Lunch/Science Talk Earth's ice in a time of climate change	Tucker, Markus
12:45-1:30pm	Planetary Science	Greeley, Green
1:30-2:00pm	Discussion	
2:00-2:45pm	Earth Science	Tapley, Freilich
2:45-3:15pm	Discussion	
3:15-3:45pm	NASA's Technology Initiative	Braun
3:45-4:00pm	Discussion	
4:00-5:00pm	Q&A with SMD AA	Weiler
5:00pm	Adjourn	

**NAC Science Committee
April 20-21, 2010
GSFC, Building 1, Room E100**

Agenda

Day 2 (Wednesday, April 21)

8:30-8:45am	Remarks and Announcements	Huntress, Feeley
8:45-9:30am	Astrophysics	Boss, Morse
9:30-10:00am	Discussion	
10:00-10:10am	Break	
10:10-10:55am	Heliophysics	Torbert, Bredekamp
10:55-11:15am	New Millennium Program	Taylor
11:15-11:45am	Discussion	
11:45 – 1:00pm	Lunch on Own	
1:00-1:30pm	ISS Utilization	Uhran
1:30-1:45pm	Discussion	
1:45-2:15pm	Public Comment	
2:15-3:00pm	Findings and Recommendations	
3:00-3:10pm	Final comments	
3:10pm	Adjourn	