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SCIENCE COMMITTEE

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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 meeting. Dr. T. Jens Feeley, Executive Secretary of the committee, made some brief logistical announcements.

Budget Update/Q&A with the SMD AA

Dr. Edward Weiler, Associate Administrator (AA) of the Science Mission Directorate (SMD), reported that very few changes had occurred within SMD since the Science Committee's previous meeting in April. Recent events of note include the receipt of first-light images from the Stratospheric Observatory For Infrared Astronomy (SOFIA) in May 2010, including an infrared image of Jupiter and another of M82. These early images demonstrate that SOFIA can meet its Level 1 specifications. The Mars Science Laboratory (MSL) rover underwent its first full functional test as a rover, with wheels and actuators installed, and met all its functional objectives. The mission is still 15-16 months from launch, but good progress has been made.

The new space policy released by the White House on 28 June is consistent with the way NASA does business. Dr. Feeley added that the new policy restores the full breadth of what NASA has been doing for years, particularly in that the policy focuses on cooperation rather than unilateral concepts, and provides a motivation for space exploration by setting goals for human spaceflight, as well as more emphasis on technology, aeronautics and science. Dr. Weiler noted that the House Appropriations Committee basically passed the NASA Science budget as is, with some proposed funding being re-directed ($16M for carbon monitoring pilot programs and $9.3M for the planned Europa-Jupiter System Mission (EJSM). The marked-up Appropriations bills also include NASA's requested language for a restarting domestic production of Plutonium 238 (Pu-238). The practice of full-cost management has been suspended, although NASA will still track civil service labor costs separately.

Dr. Weiler reported that Senator Barbara Mikulski (D-MD) has asked for an independent review of the James Webb Space Telescope (JWST). This request was not unexpected and NASA has already commenced its own reviews of the mission. Dr. Weiler noted that he intended to withhold additional FY11 monies from JWST without a go-forward review; a total of $20M in 2010 and $60M in 2011 has already been added to the mission. The mission's prime contractor is now reporting another over-run. Independent reviews of JWST are ongoing at Goddard Space Flight Center to address such questions as to what level of optical testing of the entire observatory is necessary. Most data should be available by Fall 2011 for the Congressionally requested review. Any further monies will require approval from the NAC Science Committee and the Astrophysics Subcommittee (APS).

Commenting on the Science Committee's action to SMD to consider the International Space Station (ISS) as a platform for earth and space science, Dr. Weiler expected that SMD's four science divisions would conclude that ISS should be considered in a competitive proposal setting. Dr. Huntress asked Dr. Weiler to comment on a cost-overrun report due to be released by the National Research Council (NRC) later that morning. Dr. Weiler felt that not many new ideas had been put forth in this latest report, other than the concept of trying to pull together all the different methods of cost control to a more systematic approach, which he thought was a good idea. Dr. Weiler added that in the last decade, NASA has put forth efforts to change its costing procedures and is now beginning to see some results. In a typical Announcement of Opportunity (AO), the Agency has been making down-select decisions based on costs. The MAVEN (Mars Aeronomy), Juno (Jupiter), and Gravity Recovery and Interior Laboratory (GRAIL) missions have all been on track as a result. SMD programs are currently budgeted at a 70-percent confidence level. Dr. Noel Hinners commented that NASA centers are motivated to give the optimistic cost estimates, and that copious funding reserves in the early phase of a mission tend to get eaten up with non-essential items. Dr. Tapley wondered whether overspecifying requirements could be a cost driver. Dr.

Weiler observed that previous Decadal Surveys have also notoriously under-costed missions, as human factors lean toward optimism. Dr. Alan Boss felt that the inclusion of cost estimation exercises in upcoming Decadal Surveys will be extremely helpful in solving the problem of underestimating mission costs. Dr. Huntress commented that SMD has done an excellent job in tracking down cost issues, and that success is just starting to be evident. Dr. Roy Torbert noted that the Heliophysics Decadal Survey is also considering cost models and a new look at the "science pie," adding that there is an inexorable growth process in missions, partly as a result of NASA policy. There is great concern in the community for new AS9100 rules in the NASA Explorer program, which is thought to triple quality assurance costs. Dr. Weiler commented that cheap failures are equally undesirable.

Dr. Huntress requested that Dr. Hinners keep up with how NASA is tracking the NRC cost-overrun report, and to make a presentation at the next SC meeting. Dr. Hinners reported that plans are in place with the Office of the Chief Engineer (OCE) and Associate Administrator Chris Scolese to examine the report and other studies and develop a small number of operating principles for reducing cost overruns. He noted that some of these ideas have already been adopted by SMD, and agreed that the external world does not understand the challenges of new NASA missions. NASA must educate the the GAO and the Hill as to the nature of the business. It is time to do some success reviews to understand how well-costed projects have come to be. Dr. Weiler asserted that the Hubble Space Telescope overran its initial estimates by 300 percent,. HST was underfunded in Phases A and B and was still dealing with technical difficulties in Phase D. He noted also that JWST had $2B spent during Phases A and B, and every technology was at Technology Readiness Level 6 (TRL-6) by the time of the Preliminary Design Review (PDR). He suggested that Phil Sabelhaus, the JWST project manager be tapped to deliver a briefing on what went wrong.

Dr. Boss suggested that NASA develop Lessons Learned reports on successful missions. The committee concurred with this idea. Dr. Jon Morse noted that the NASA centers generate Lessons Learned reports after launches, which are stored in a database, nominally under the management of the NASA Engineering and Safety Center (NESC). Dr. Hinners felt there was an insufficient budget to support Lessons Learned reporting, and that such reporting was limited to technical factors, not costing and scheduling activities; he added that he would confer with Mr. Bryan O'Connor, NASA's Chief of Safety and Mission Assurance, on this matter. Dr. Weiler suggested that a psychologist might be helpful in elucidating what type of person runs a successful and cost-controlled project. Mr. Michael Moore commented that many organizations with high-value, high-risk jobs routinely screen candidates for the presence of certain personality traits. Dr. Lean recommended that NASA strike a balance between new investigators with new ideas and established principal investigators (PIs). Dr. Huntress observed that new PIs need a good experienced project manager and management team to appropriately manage a mission.

Dr. Tapley asked if NASA were interacting with China. Dr. Marc Allen replied that NASA has in place a number of expert teams to start consultation; there has been a little relaxation at the top in the human space flight program, but the process is slow. Dr. James Green reported progress in the area of data exchange, particularly in the area of cultural differences. Serious collaboration, however, is probably far off. Dr. Torbert commented on the noticeable cost risk factor in international collaborations. Dr. Weiler noted that international collaborations signified a risk-benefit trade-off, and that the key to international collaboration is keeping the interfaces as simple as possible. He added that such interfaces were functioning smoothly in the Mars program, and that more of this collaboration will be necessary for larger missions in the future. Ambitious missions are going to cost a lot of money.

NRC Study on Controlling Cost Growth in SMD Missions

Dr. Ron Sega presented an overview of the National Research Council (NRC) Study on Cost Growth in NASA Earth and Space Science Missions (note: this study was released on July 13, 2010, during the

course of the meeting). Dr. Alan Angleman, study director, and Dr. Dick Roberg, briefing planner, introduced themselves.

Dr. Sega explained that the study resulted from Congressional language requesting an identification of primary cost drivers in NASA's Earth and space science missions. The study also developed recommendations on reducing such growth. There was particular emphasis on reviewing existing cost-growth studies, assessing whether key causes remain applicable, evaluating the effectiveness of current NASA practices, and identifying new strategies to contain cost growth. Inputs to the study included team experience, earlier studies (December 2009 to present), and other information (visits to centers, interviews). Dr. Sega reviewed the committee membership, which reflected deep experience in industry, NASA management, academic science, and cost estimation.

The primary conclusion of the study is embodied in a recommendation that NASA adopt a comprehensive, integrated cost-containment strategy. The study finds that while this strategy has not yet been instituted, it recognizes that NASA has made some promising steps in the right direction (e.g. 70 percent confidence levels in cost estimates).

The study was initiated in September 2009 and made extensive use of webinars, teleconferences, meetings, and site visits. Cost growth factors identified from previous studies include overly optimistic initial cost estimates, project instability (internal changes such as re-scoping, de-scoping, budget changes, technical factors), problems with instruments and technology development, launch service costs, and schedule growth. Reducing the risk of maturation early in technology development was also tied to cost. Consistency in start and end points was also noted as a controlling factor (e.g., ensuring a number of tasks/requirement are complete by PDR). Dr. Angleman commented that the system is incentivized to produce low-cost estimates, while the impact of mission complexity on cost estimates is not well understood.

Dr. Sega briefly reviewed a typical mission life cycle, observing that a solid cost estimate is needed by PDR, which requires sufficient work in Phases A and B. Different studies calculate cost growth over different portions (start and end points) of a mission life cycle, thus the NRC committee adjusted study time periods as best as possible to observe trends. The study found that there tended to be significant cost growth in the period between the Critical Design Review (CDR) and launch, leading to the conclusion that a greater investment in Phase A and B would solve this problematic trend; existing studies indicate that CDR is not as strong as it should be. In ranking of cost growth from large to small missions, 14 missions out of the 40 considered accounted for 92 percent of cost growth. The 14 missions tended to be larger flagship missions (with exceptions). Differences between Earth Science and Space Science missions, with respect to cost growth from Phase B to D, were not considered significant. In comparing directed and competitive, PI-led missions, the study also found no significant difference. In considering the percent of schedule and cost growth, the correlation was found to be reasonable between cost and schedule: about half the missions fell above the 15 percent Nunn-McCurdy requirement for notification to Congress . In the 14 missions that accounted for largest absolute cost growth, there was a correlative relationship between cost and schedule. Dr. Sega went on to review individual findings and recommendations:

Overview of recommendations and findings

Finding: Unrealistic initial cost and schedule; the current system incentivizes optimism.

- Recommendation: NASA should strengthen its use of cost estimates, particularly expanding NASA's ability to conduct parametric cost estimates, and by obtaining parametric cost estimates at CDR and comparing them to other reviews, should reconcile significant differences.

Dr. Weiler remarked that the selections he has made in the last two years have been the lowest cost-risk selections, ensuring that unrealistic cost selections were not incentivized, and was nonplussed as to how NASA can get this message across to contractors. Dr. Sega noted in this context that time, effort and resources must be spent in order to drive down risk by maturing key pieces of the mission during Phase A and B. This approach would ensure that the cost estimate contains actual data from an engineering prototype, and not a model. Dr. Huntress pointed out that SMD has been trying to institute this practice. Dr. Sega responded that the key is to get data upon which uncertainties can be driven down. Dr. Boss noted that 2 or 3 independent estimates may be needed to accomplish this feat. In response to a question about Phase B spending, a meeting participant commented that in some competed missions, only 1% of mission costs were spent by Phase A. Dr. Torbert called for more honest assessments of technical maturity in mission timelines.

Finding: Measurement of cost growth.

- Recommendation: NASA, Congress and the Office of Management and Budget (OMB) should consistently use the same method to quantify and report cost.

Finding: Differences between Announcement of Opportunity (AO) and directed missions.

- Recommendation 1: NASA should pay particular attention to large, $500M+ missions, especially directed missions.
- Recommendation 2: NASA should continue to emphasize science in AO missions, and ensure that AO proposal selection and project management contain incentives to establish realistic cost estimates and minimize cost growth at every phase of the mission life cycle.

Finding: Technology development.

- Recommendation: NASA should increase emphasis on technology development in Phase A and B.

Finding: Instrument development.

- Recommendation 1: To prevent delays and cost increases, NASA should initiate instrument development well in advance of starting other project elements, and establish a robust instrument technology development effort relevant to all classes of missions.
- Recommendation 2: NASA should ensure that instrument and technology development is included in Decadal Survey and other strategic efforts.

Finding: External project reviews.

- Recommendation: As an increase in reviews is viewed as counter-productive, NASA should reassess its approach such that major reviews occur only when specified success criteria are likely to be met.

Finding: Launch Vehicles.

- Recommendation: Prior to PDR, NASA should minimize mission-unique launch site processing requirements. NASA should also select launch vehicles as early as possible in the mission-planning process.

Dr. Weiler and Dr. Sega briefly discussed the application of these recommendations to past missions. There was general agreement that for some missions the Level 1 requirements may be too aggressive, leading to excessive testing, and that acquisition cycle times requiring early delivery tended to increase contractor profit. Managing the budget at program level was considered key to controlling these factors.

Dr. Torbert expressed concern about the waste of reserve funds by contractors. Dr. Weiler agreed that schedule reserves were being used to cover poor performance. Dr. Burns remarked that AO missions were felt to be not so problematic as presented by the report, and instead felt that cost growth tended to be more of an issue in larger missions. Dr. Sega noted that average cost growth for AO missions was larger than directed flagship missions (25% vs. 15 percent), but that the overall dollar amount was less. Dr. Huntress felt it would be helpful to further break the data down to Phase A and B spending in these cases.

Heliophysics Division Status

Dr. Richard Fisher, Director of the Heliophysics Division (HPD) and Dr. Roy Torbert, Chair of the Heliophysics Subcommittee, presented a status of the HPD. Dr. Fisher provided a brief overview of mission progress. The Radiation Belt Storm Probes (RBSP) mission is proceeding to a 2012 launch. Solar Probe Plus (SPP) has had its Phase A contract awarded. The Solar Orbiter international collaboration will begin major reviews in September 2010. The Magnetospheric Multiscale (MMS) mission CDR is due to took place in late August 2010; its instrument and spacecraft CDRs are in progress. IRIS, an Explorer mission, will have a major confirmation review in late July 2010. Instruments from the Deep Space Climate Observatory (DSCOVR; formerly known as Triana) spacecraft continue to undergo assessment. The Sounding Rocket program continues to assess the anomalous performance of Black Brant motors, which have been removed from flight status. The launch schedule is being reassessed.

Public outreach activities include a STEREO application (called "3D Sun") which is now popular on the iPhone, and planetarium shows at the American Museum of Natural History that are based on real data. NASA also released an educator's guide and DVD that has been very well received, representing an investment of $1.5M that is expected to reach 2 million students this Fall. Dr. Fisher displayed loops of the Sun as recently imaged by SDO.

Heliophysics Subcommittee

Dr. Torbert reported on membership changes in HPS. There were no new findings from the subcommittee's most recent meeting. Science highlights in HPD include novel observations from the Aeronomy in Mesosphere (AIM) mission, ice voids in mesospheric clouds that were unknown before the AIM launch. Summer features the period of coldest temperatures in the mesosphere, when the atmosphere has cooled by expansion. Mesospheric clouds are thus a sensitive indicator in that they are affected by a 10°C change. This finding also suggests that if more CO_2, which is an efficient radiator, is added to the mesosphere, even greater cooling will occur. CINDI data have shown Earth's ionosphere to be much colder and deeper during recent peculiar solar minimum. The Interstellar Boundary Explorer (IBEX) mission has provided results concerning neutral particles in the inner Solar System, presenting a new paradigm for the flow of interstellar medium through the heliopause. Exactly why the magnetic field impacts neutral particles remains controversial

Dr. Torbert noted that lack of subcommittee findings stems from the uncertainty in flight projects and their interaction with the various Virtual Observatories (VOs). HPS has been engaged in discussing how these VOs should interact, longevity, future prospects. Dr. Fisher explained that VOs derive most of their support from extended mission operations and flight programs; the question that HPS is considering is what happens after missions end. Dr. Lika Guhathakurta added that the VOs also provide observations for the international communities, which are now using data faster than the U.S. community. Another issue under review is the balance of support for modeling and data analysis. As to utilization of ISS, the Heliophysics community sees three possibilities: Supporting Research & Technology (SR&T), Geospace SR&T, and Explorer Missions of Opportunity. Examples of successful Heliophysics deployments in the past include floating potential measuring units, and a Remote Atmospheric and Ionospheric Detection System. Future ideas are focused on remote sensing of the ionosphere/thermosphere/mesosphere (ITM), including multiple cast-off free flyers.

Earth Science Division Update

Dr. Byron Tapley reviewed Earth Science Subcommittee (ESS) findings from its March 2010 meeting. The Earth Science Division (ESD) plan emanating from the 2011 budget takes into account both the 2010 ESD Science Plan and the ESD Climate Initiative Plan, which are currently in committee evaluation. ESS regards the Challenge of Climate and Environmental Change report as a positive statement from a community point of view. Of the 15 NASA Earth Science Decadal Survey missions, all Tier 1 missions are covered by the proposed 2011 budget. A total of 17 missions are planned by 2018, representing roughly 2 satellite launches per year. As a result, ESS harbors growing concerns over launch vehicle costs and capabilities, noting that ESD is still lacking a medium-class vehicle (Delta II equivalent). NPOESS, now known as the Joint Polar Satellite System (JPSS), also remains an issue of concern. Measurement accuracy, calibration, and stability of instruments remain worrisome, as well as the continuity of the mission within the context of program definition uncertainty. ESS has recommended that an appropriate forum be established to ensure accurate and appropriate measurements, in light of conflicting data product requirements among the agencies involved. Dr. Weiler, in response to these concerns, remarked that the National Oceanic and Atmospheric Administration (NOAA) has made clear its leadership on this mission. Dr. Freilich added that SMD has established an equivalent division to NOAA's JPSS office to carry out this work, although NOAA retains responsibility for management of funding and requirements. ESD research programs also utilize these operational long-term missions, but are connected to them through the research side. ESD is in the process of working out those communication paths between NOAA and NASA. Dr. Weiler recommended that the Earth Science Subcommittee (ESS) establish a link with Mr. Marcus Watkins, SMD's Director of the Joint Agency Satellite Division, that oversees JPSS for NASA. Dr. Huntress asked if cost was involved for science data. Dr. Freilich responded that cost was barely an issue; the issue is that NPOESS was never managed with a set of requirements until now. NASA is having substantive talks with NOAA to identify what NOAA wants to pay for. Dr. Huntress agreed to take the ESS recommendation on JPSS to the NAC.

Regarding Earth observations from ISS, ESS considered the costs and potential science quality of such observations within the limited utility of ISS. ISS is not a stable platform and views only 75 percent of Earth's surface. ESS will continue to consider ISS utilization within the criteria for science measurement requirements, such as simultaneity with other measurements, global coverage, etc. Missions evaluated in this context were SAGE-3, Orbiting Carbon Observatory-2 (OCO-2), a scatterometer, and GPM. Only SAGE-3 was considered a good example and is now scheduled for ISS. In an initial review of the disadvantages of CO_2 measurement from ISS, ESS concluded that OCO-2 was not appropriate for ISS; however, deliberations continue

ESMD Status

Mr. Douglas Cooke presented a status of the Exploration Systems Mission Directorate (ESMD), which is currently in the midst of dealing with changes and budget planning. In the budget request for 2011, ESMD has been challenged with a new approach to Exploration. Programs have been laid out in the areas of heavy lift/propulsion; technology development and demonstration for Flagship technologies; continuation of an existing program in developing basic technologies to support future human missions; precursor robotic missions; human research to prepare for long-term space flight; and expanding commercial crew capabilities to ISS. As of 15 April, ESMD was charged with developing an emergency rescue vehicle, and is still working on how this will fit into budget. At present, ESMD has undertaken a phased development strategy for the rescue vehicle.

ESMD has also created "Point of Departure" solutions, defined as strawman plans for a new start. This concept has been refined through a workshop and Requests for Information (RFIs), and there is now a potential set of content. Teams and centers have been identified for program management of yet-to-be-

formulated programs and are awaiting budget enactment. Within the Flexible Path initiative, a first mission to a near-Earth object (NEO) or asteroid is slated for 2020/2025. Dr. Huntress inquired whether ESMD was building in to potential changes. Mr. Cooke reported that ESMD was indeed engaged in examining "what-if "scenarios with the Office of Science and Technology Policy (OSTP) and OMB, preparing to answer inevitable questions. The Enabling Technology Development (ETD) program (Moon) is being re-planned within the Flexible Path and is expanding to more external opportunities, some of which will move into the Flagship area. Scout missions are planned in the precursor line (similar to LCROSS). ESMD also has a new commercial crew line, and the emergency rescue vehicle line is being derived from Orion. ESMD regards precursor missions as a way to gain knowledge, requiring work with the science community to determine issues such as hazards and other parameters of exploration.

Another ESMD activity of note is the creation of the HEFT team, which will develop an architecture for future human space flight, and will be evaluating mission concepts, mission approaches, objectives, and anticipated funding levels. HEFT deliverables include identifying critical stakeholders, figures of merit (FOMs), guidelines and approaches for a set of reference missions, evaluation of portfolios in the investment strategies using FOMs, and tailored communication products for steering council and stakeholders.

ESMD is also developing top-level objectives and principles for robotic missions, and anticipates overlap with science objectives. The intention is to compete some of the payloads and partner with international agencies. The first planned mission will be to an NEO (perhaps to multiple objects). Other potential robotic missions include a lunar lander, another more detailed view of an NEO of interest, and a Mars precursor in 2018. Asked about the scientific value of visiting an NEO, Mr. Cooke cited understanding of hazards; NEOs are dusty and could yield insight into a broader set of environments, or resource characterization. Dr. Burns remarked that there could be 20-30 years between visits. Dr. Hinners felt that visiting any type of NEO would help expand capabilities. Dr. Greeley asked if the Lunar Exploration Analysis Group (LEAG) was still able to provide relevant information to this effort. Mr. Cooke agreed, adding that ESMD's the current approach does not abandon the Moon. Dr. Greeley added that the Small Bodies Analysis Group (SBAG) could also be helpful to ESMD. Mr. Cooke concurred.

The ETD will interface with Dr. Robert Braun's new Space Technology program, the ISS research program, Science and Aeronautics mission directorate, and international partners. The ETD program structure is grouped into technology domains such as Entry, Descent and Landing (EDL), Extravehicular Activity, In Situ Resource Utilization, Life Support, etc. ETD is now putting together various demonstrations as a Point of Departure exercise.

ESMD's Flagship Technology Demonstration line is now testing technologies for the larger mission classes, such as aerobraking, EDL, automated rendezvous and docking (ARD), and advanced in-space propulsion, overlapping with planetary missions and closed loop Environmental Control and Life Support (ECLS).

Mr. Cooke provided some illustrations of how exploration can enable science, and opportunities for mutual benefit. The Lunar Reconnaissance Orbiter (LRO) was a good example of a mission that answered science and human mission questions, and was also well executed and well instrumented. In September, ESMD will transfer LRO to SMD for at least another 2 years of operation. Other examples of ESMD/SMD collaboration include LASER proposals from the Research Opportunities in Space and Earth Science (ROSES) competitions, instruments for the Mars Science Lander (MSL: a radiation experiment will be flying on MSL, as well as an instrumented heat shield for Mars entry); and a University Student Launch Initiative. Lunar architecture studies helped to build candidate requirements

for the Constellation program, including delivery and return mass and volume; human research needs, environment characterization, and surface exploration sortie mobility.

ESMD using a "science" systems engineering process to build requirements, recognizing that it is important to have a high science content to these missions. Mechanisms to communicate these requirements will take the form of joint working groups and workshops. Mr. Cooke welcomed further suggestions. He noted that the Exploration of NEOs Objective workshop, which will be held August 10-11, 2010, in Washington, D.C., has 65 percent of its invitees from academia.

The committee briefly discussed ESMD's plans. Dr. Hinners remarked that heavy lift vehicles are expensive, and questioned how NASA could maintain this capability without having it drive the total budget. Mr. Cooke noted that ESMD is addressing how to support heavy vehicles on the ground as well as the high fixed costs of the infrastructure. Dr. Burns commented on the exciting opportunities for synergy, and suggested ESMD consider how to mesh with Decadal Survey results. Mr. Cooke agreed that the Decadal Survey could provide value to ESMD. Asked how precursor missions would be selected, Mr. Cooke reported that the first few robotic missions would probably be directed, but would allow some competition for instruments. The destinations in part will be determined by opportunity (such as the 2018 Mars opportunity). ESMD remains interested in further input from the science community. Dr. Weiler remarked that LRO was good for SMD because it was free, and emphasized that there is no budget in SMD to carry out the missions ESMD is outlining. Mr. Cooke felt that ESMD could provide flight opportunities for instruments, and might consider paying "full freight" for some of these missions. Dr. Weiler reiterated that SMD strives to carry out the best competed science, and not just more science. Dr. Burns asked if Headquarters might tweak the SMD budget to take advantage of ESMD opportunities. Dr. Weiler felt this was possible only within the philosophy of best science. Mr. Cooke said that he was open to discussion. The committee urged ESMD to take advantage of science advice from existing assessment groups and to proceed with detailed discussion on joint ESMD/SMD sponsorship of these missions.

Earth Science Division Update

Dr. Michael Freilich gave a programmatic update of the Earth Science Division (ESD), beginning with recent highlights. ESD has made significant contributions in responding to natural and anthropogenic disasters, including provision of MISR imaging of volcanic ash plumes in Iceland. Many airborne and satellite-borne ESD instruments are continually imaging the BP Gulf oil spill, helping to initialize trajectory models and estimate oil concentrations. ESD has received some recognition for this effort, having effectively put together a rapid response management scheme.

ESD is in the process of passivating the ICESAT-1 satellite in advance of a de-orbit/re-entry no earlier than 29 July. All instruments for the Aquarius/SAC-D (sea surface salinity) mission have been integrated in preparation for an April 2011 launch. The NPP (NPOESS Preparatory Program) mission has had all 5 of its instruments mechanically integrated; the ground system remains on the critical path for an October 2011 launch readiness date. The GOES-R cryocooler has been transferred to the OCO-2 project, representing a successful interaction with NOAA. JASON-1, a nadir altimeter, is well past its mission baseline, therefore NASA, EUMETSAT, NOAA and other agencies have met to determine status of JASON-1 and to preserve its orbit. Five selections were made at the end of May for ESD's first Venture-class missions: these are AirMOSS, ATTREX, CARVE, DISCOVER-AQ, HS3, involving 23 institutions in addition to the NASA centers.

Dr. Freilich reviewed progress in carrying out the Earth Science Plan, filling in previously embargoed information on the $2.4B augmentation to ESD over 5 years. All Foundational missions are to be launched by mid-calendar year 2013 (Glory, Aquarius, NPP, LDCM, GPM), building on an existing balanced program. The 2011 budget will enable OCO-2 development by 2013, and will allow acceleration

of Decadal Survey missions, and the launch of all 4 Tier-1 missions between 2014 and 2017. ESD also plans to expand and accelerate Venture-class missions with annual solicitations for one or more major Earth-observing flight instruments and biannual calls for airborne and small mission solicitations, with the first small satellite selections to take place in 2012. The current plan is to have multiple instruments on the shelf in varying stages of development. Questioned about utility of the instrument program, Dr. Freilich stressed that is an experiment and is not the only ESD approach to instrument development. Venture-class will be considered complementary to the systematic missions. Dr. Tapley categorized the experimental program as valuable and agreed that flight instruments in the Venture class need to be fairly mature.

SAGE-III, a Climate Continuity mission, has been built and is scheduled to fly on ISS in late 2014. The GRACE-FO follow-on mission is now scheduled for launch in late 2016, and PACE is scheduled for 2018/19. The 2011 budget also accelerates all Tier-2 Decadal Survey missions to launch in the 2019/20 period. Plans are under way for OCO-3 in 2015. The budget also enables key non-flight activities such as a multi-year carbon monitoring pilot, SERVIR expansion, and expanded NASA support for the GLOBE program. Dr. Freilich mentioned a recent budget infusion in France that helped to contribute substantially to the SWOT mission. ESD is getting into the business of sustained, precision measurements for Earth Science and is finally in the position to make real progress on the Decadal Survey. Dr. Tapley cautioned that technical and management problems remain. Dr. Freilich noted that linking various components of the programs to maintain an integrated program is an important priority, in order to make possible sustained measurements of CO_2 in the ocean, atmosphere, and terrestrial realm.

Dr. Freilich was encouraged by the National Space Policy, which supports the national priority to advance understanding of the Earth and obtain societal benefit from the Earth-Observing system, details an overall philosophy to support the transformation of NPOESS, and clearly directs the Department of Interior (DOI) and NASA to develop a sustained Earth-monitoring system. Dr. Hinners commented that the mission would benefit from recent political changes, but stressed the need to obtain broad apolitical support for this activity. Dr. Freilich reported that he had sensed very strong bipartisan support for this program, a result of public recognition of the importance of environmental science.

Astrophysics Division Update

Dr. Alan Boss, Chair of the Astrophysics Subcommittee (APS), reported science highlights within the Astrophysics Division (APD), including results from HST, which discovered a star essentially consuming a planet (WASP-12b), an event that was inferred by the presence of aluminum, manganese, and tin in the stellar atmosphere. He also presented a view of the Heart and Soul nebulae as seen from Wide-field Infrared Survey Explorer (WISE). The Swift satellite detected active black holes in a number of merging galaxies (as evidenced by hard x-rays), enabling correlations with the optical counterparts of the emitting regions. GALEX data from the galaxy IC 3418 in the Virgo cluster was also highlighted, which revealed an ultraviolet tail for IC 3418 produced by interaction with hot gas in Virgo. Numerous recent Astrophysics press releases were also noted.

The most recent APS meeting addressed ISS utilization; Dr. Boss reported that an Astrophysics opportunity has been specifically called out in the ROSES solicitation, in addition to AOs issued in the ordinary course of proposal business. As to specific ISS science utilization points, APS supported the specific ROSES solicitation, but considered it premature to recommend a line item. The subcommittee also considered that there might be a stronger case for proposals for peer-reviewed technology, such as telescope-pointing technology. However, APS issued no specific finding on ISS utilization. Dr. Burns felt the ISS utilization presentation to the subcommittee had not been well focused, and that some APS members had felt overwhelmed by a crowded agenda. Dr. Boss agreed that the subcommittee had been caught cold, and has discussed ways to improve meeting preparation. Dr. Burns felt that despite some

prior notice, the APS would have benefitted from advance reading material. Dr. Morse noted that the APS Executive Secretary had received that message and would act accordingly, bearing in mind the rules that govern Federal Advisory Committee Act (FACA) meetings. Dr. Huntress remarked that he was satisfied with what he has heard from the subcommittees in regard to ISS utilization.

Dr. Boss discussed the APD's 2010 Senior Review request that the Chandra Guaranteed Time Observer (GTO) policy be revisited. The APS discussed the advantages and disadvantages of maintaining the Chandra GTO policy, noting that after a review in 2002, Dr. Paul Hertz had written that Chandra was best served by the current policy. The APS similarly recommended that the current GTO policy be maintained, at least until the Chandra Users Group could be asked to review the issue. The APS also reviewed Government Performance & Results Act (GPRA) metrics, evaluating a large number of science highlights. The APS consensus was Green on all specific science research objectives for 2009-10.

Dr. Jon Morse, Director of APD, presented programmatic highlights. APD recently completed a Senior Review of 11 operating missions, out of a total 15 missions in operations. He noted that a number of operating missions will decline in the next decade due to natural attrition: Kepler and Spitzer will trail off and other missions will deplete their cryogens. APD hopes to begin peer-reviewed science with SOFIA at end of 2010, and continue with hundreds of hours per year from 2011-2014. Planned work in the outyears include having the "telescope flying the plane" for long-duration flights. Avionics for SOFIA will be upgraded next year. NuStar and LISA Pathfinder are in planning for 2012 launches. APD is Green across the board for operating missions. It was noted, however, that Spitzer lost some data due to a fire in a Spanish receiving station. APD is also tracking a degradation on a GALEX detector. WMAP was ranked in the mid-range by the Senior Review, and will receive more funding for data analysis. The spacecraft will then be decommissioned in September 2010. Kepler presented its first major data release in mid-June, revealing many targets; some data is being held until February 2011 to eliminate false positives. WISE cryogens are expected to last through November 2010. The NuStar mission is in the midst of optics fabrication, and is solving some problems with the mast. NuStar underwent its key decision point (KDP-C) review last autumn and is working within a slightly lower budget to a launch date of February 2012.

Recent JWST accomplishments include a delivery of microshutters to the European Space Agency (ESA), and a delivery of MIRI sub-assemblies, completion of the ISIM Structure (integrated instrument structure) cryogenic test. JWST graced the cover of Aviation Week in May and also received media coverage in New York City at the World Science Festival in June. The Astro-H mission of opportunity passed its KDP-C on 21June. Within the Balloon program, a mishap investigation board will release its results in late summer on a failed launch attempt in Australia. A report is also imminent on the failure of a 14-million-cubic foot (mcf) balloon in Antarctica. APD is continues to work toward its goal of 25-mcf flights at mid-latitudes. Named fellowships in Astrophysics are due to be announced soon. Personnel changes include the departure of Dr. Michael Salamon and the addition of Dr. Bill Danchi. APS alumnus David Spergel was one of the recipients of the Shaw award. The Senior Review 2010 is now complete and initial guidelines have been released for 2013 and 2014. The Astro 2010 Decadal Survey is expected to be released in late Summer 2010, and the division is now scheduling to get briefed for the OMB budget submission. Dr. Burns commended Dr. Morse and other members on the outcome of the Senior Review, which produced logical, if painful, results. Dr. Morse commended Craig Wheeler for his chairmanship of the review. APD is also gearing up to review research and technology portfolio in 2010/11. Dr. Morse briefly reviewed budget changes, and noted the previously discussed placement of $60M in the JWST line in FY11. He also highlighted estimates of the budget runout to 2023, demonstrating the resource data that had been provided to the Decadal Survey in an effort to produce an in-guide plan, as well as an over-guide plan.

Dr. Morse reviewed the history of JWST funding. Phase A was begun in 1999, and a total of $2B was spent in Phase A and Phase B. A Technical Non-Advocate Review (TNAR) was held in 2007 to address JWST's top ten challenging technologies, which assessed the telescope's componentry and primary mirror segment schedule. By summer 2011, all mirrors will be coated and ready to test. The NIRCam near-infrared camera had been on the critical path until recently, but has turned the corner on design activities and is expected to be delivered next year. JWST's Mission CDR was rated Pass, but issues were identified; these were regarding the verification program and risk reduction; structural margin; provision of closure plan for all open RFAs; and completion of activities related to the recovery of observatory thermal margins.

JWST programmatic issues are rooted in part in Northrop Grumman Aerospace overruns. NIRCam was bid at $50M and is now over $200M. ISIM is also projecting cost growth. Schedule and budgetary issues have been identified. JWST's recent funding history includes a roughly $200M overguide with respect to the number quoted at the confirmation review. The Standing Review Board's (SRB) prediction has not been reliable to date. APD is requesting a rationale from the SRB in order to address this matter. Dr. Morse expressed concern that the Decadal Survey was given an optimistic worst-case scenario for JWST.

Subcommittee members debated the significance and utility of a 70 percent confidence level, which seemed to be differentially applicable to small versus large missions. Dr. Morse pointed out that NASA also uses grass roots and mission analogy methods, in addition to independent cost estimates, to predict costs in the future. Dr. Weiler added that it is difficult to predict the costs of revolutionary, new technologies. Dr. Burns asked how JWST could have run over to such a degree if the mission had followed suggested guidelines. Dr. Morse attributed the problem to mission complexity, and the difficulty of doing something brand new. Dr. Levy questioned whether the cost differential could be attributed to behavioral problems during the bidding or during the course of the project. Dr. Fisher felt the overrun was based on the number of mission elements, interconnections, diversity, and adaptability of system. Dr. Morse reviewed near-term plans to deal with the mission, including the placement of an independent assessment team at Johnson Space Center (JSC), to ensure that only the testing needed to verify requirements is done. In addition, the team will try to identify which science requirements are driving cost growth (with an eye to possible de-scoping activities). APD will have a discussion with Administrator, and an Agency Program Management Council will be held in November 2010. APD hopes to have much more information at the next meeting of the NAC Science Committee.

Dr. Hinners asked if the Mikulski review team was to be independent of NASA's reviews. Dr. Morse expected the Mikulski team to assess the entire project. Dr. Morse asserted that JWST is getting much more technology for roughly the same amount of money as HST. Dr. Weiler commented that holding funding for the mission at its current level could mean an up-to-4-year slip of JWST. Dr. Weiler noted that consideration of any additional funds, over and above the current budget for JWST, would be brought to the Astrophysics Subcommittee and the Science Committee for discussion. He asked that the committee keep in mind that no other space agency can do what NASA is doing. Dr. Morse agreed to bring scenarios back to the committee for further evaluation.

Wednesday, July 14, 2010

Planetary Protection Update

Dr. Eugene Levy, Chair of Planetary Protection Subcommittee (PPS), addressed the linked science and regulatory roles of the PPS. The subcommittee's regulatory role dates to the 60s, in particular to language in the Outer Space Treaty of 1967, Article IX, which reflects both the science interests and safety concerns of planetary protection. The science role of PPS is in ascertaining the nature, distribution, varieties, movement and origin of life, which is also one of the motivating roles of NASA. PPS must also

consider the preservation of the environment so that these questions can be pursued, and guard against the inadvertent spread of life to or from the Earth. He noted that NASA has been amongst the world's leaders in expanding the understanding of biology on Earth.

Planetary protection covers both forward and backward contamination, with a particular interest in protecting terrestrial biota. Issues of back contamination impose a set of requirements in exploration and scientific investigations to control this risk. Control of forward contamination aims to preserve the biological integrity of extraterrestrial environments in order to enable exploration. The guiding principle is facilitating science. There are no zero-risk scenarios other than inaction, which is considered unacceptable. Therefore each planetary protection judgment balances the risks against the value of scientific investigations.

Restructuring of the PPS continues to evolve. Prior to Spring 2010, the subcommittee had not met since November 2008. Currently, PPS is addressing recommendations that had been left unattended due to lack of response and communication between the NAC Science Committee and PPS. Dr. Burns addressed one of the reasons for the hiatus, in that there had been a request from the PPS itself to be placed in a different part of the hierarchy, occurring at the same time as the transition of the Administration in 2008.

PPS is now in the process of resubmitting recommendations. First, PPS endorses consensus of the COSPAR to protect the Moon as a category II object. Dr. Tapley remarked that it seems the Moon has been ignored in the scheme of planetary protection. Dr. Levy agreed with this assessment. Dr. Cassie Conley noted that in the past, the Moon and Earth had been considered one system, in which case Planetary Protection Category II imposes requirements for documentation, but no operational restrictions on that body. There is no concern that humans can contaminate Moon, but there is an interest in what is sent to the Moon, particularly in areas of potential biological significance.

PPS also recommends that NASA pursue appropriate avenues to protect sites of past human activity on the Moon, and to consider how NASA implements the Space Treaty in the context of commercial activity. Lastly, PPS is requesting a change in structure that will allow direct input of the subcommittee to the NAC and the NASA Administrator, as well as to protect integrity of the Planetary Protection Officer (PPO) position.

In closing, Dr. Levy commented on PPS concerns over insufficient attention to the development of technologies for planetary protection, such as sample containment. This issue will be a focus of future meetings.

Dr. Cassie Conley, PPO, presented an overview and status of Planetary Protection at NASA. The philosophy of planetary protection is rooted in seeking to understand the characteristics of the Solar System that support life, understand how life began, and to determine whether life has evolved elsewhere in the universe. Because it is clear that there is a great diversity of planets and satellite environments, NASA must be concerned over what its spacecrafts bring to other environments. For example, when transporting a heat source to Mars, there is the potential for large-scale contamination. The Planetary Protection policy at NASA reflects the tenets of the Outer Space Treaty, appoints a PPO, and is shaped by advice from the NRC, NAC, subcommittees, and other advisory entities. Specific policies for robotic missions are embodied in NASA documentation. Future requirements for human missions are being studied with a broad science and exploration focus. To that end, PPS includes expertise on ethics and biocontainment, in addition to a range of planetary scientists.

The NASA PPO is responsible for managing Planetary Protection policy, certifying that missions are Planetary Protection-compliant, and generally keeping the SMD AA informed. Major areas where advice

is useful are in reviewing mission implementation plans; making recommendations on specific policy that is not addressed by international policy; and in determining future directions for program (e.g., technology development and international collaboration).

Missions under the consideration of the PPO at present are the Cassini Solstice Extended Mission end-of-mission scenario (currently planning to impact Saturn in 2017); the Odyssey Mars Orbiter request to eliminate an orbit raise maneuver; the Juno project implementation approach; and mission planning for Mars Sample Return (MSR) and the Outer Planets Flagship, particularly in conjunction with ESA. NASA has had to revisit the Mars raise maneuver, as current policy is rooted in a very old assumption that Mars would be well-characterized by this time.

Preventing contamination of solar bodies is governed by a probability calculation based on a variety of parameters, including assumptions made about organisms and their ability to survive cruise phase, radiation environments, etc. NASA is still using Viking-era culture technologies while developing molecular methods for detecting life. Dr. Levy observed that most microorganisms on Earth cannot be cultured. Dr. Conley conceded this point and assured the committee that short-sequence DNA methods are in the process of being refined for Planetary Protection use. The PPO also employs risk analysis expertise to evaluate the risk of contamination. Committee members briefly debated the utility of current probabilistic methods. In this context, Dr. Conley mentioned that a request has been made to the Space Studies Board to re-evaluate the uncertainties of Outer Planet satellite characteristics. Spacecraft reliability is a different issue. The Juno mission, for instance, exceeds its requirements by a great degree. Cassini has only had one anomaly during its mission lifetime, which was attributed to a cosmic ray event, implying a high degree of reliability for future missions.

Planetary Protection is considering updates to policy and requirements in the following areas: more explicit requirements for Mars EDL; reduction of human error (such as that which contributed to the Mars Global Surveyor failure); and further analysis for Mars Sample Return, the first mission with a Restricted Earth Return designation. NASA is also reviewing bioburden requirements for a Mars orbiter. No spacecraft to Mars since Viking has been completely heat-sterilized. Currently the design of batteries and IMUs are not amenable to baking. Studies indicate that is possible to change the design to allow full-system terminal sterilization.

Dr. Hinners asked if NASA were planning a terrestrial containment facility for the Mars Sample Return mission, noting that a brand-new facility would require 10 years to develop. The primary problem with such facilities is the regulatory approval cycle; difficulties at Fort Detrick (a U.S. Army research facility located in Frederick, MD) were cited as an example of such roadblocks. Dr. Weiler felt that NASA might be wise to take advantage of the proliferation of commercial biocontainment facilities. Committee members generally agreed with this idea.

Planetary Sciences Division Update

Dr. Ronald Greeley, Chair of the Planetary Science Subcommittee (PSS), provided an update on the status of the subcommittee. PSS is cycling new members and is awaiting the release of the Decadal Survey, which may be as early as 30 September 30 or as late as 31 December 2010. The annual GPRA review for the Planetary Science Division (PSD) was completed, and all elements were found to be Green. The PSS also discussed the initiation of a study of the PSD Research and Analysis (R&A) program, prompted and bolstered by the 2010 Len Fisk study, *An Enabling Foundation for NASA's Earth and Space Science Missions.* This NRC document included 3 recommendations at its most recent meeting: ensure that activities are traceable to scientific goals and objectives; develop a management structure; and increase the number of officers. The PSS will review PSD's Strategic Goals and Objectives, assess activities, and construct a traceability matrix. The evaluation to be carried out will include metrics suggested by the

NRC. Currently the PSS is defining terms of reference, which will be followed by data-gathering, formation of the matrix, and development of recommendations, with delivery of a report a year after inception. A subcommittee working group has been stood up and will be led by Dr. Mark Sykes, who had participated in the Len Fisk study. Dr. Boss reported that APD is planning a similar study, but in the form of a Senior Review, and expressed curiosity as to why two different approaches being taken to the same subject. Dr. Morse explained that APD would be examining best practices, and that the idea of including APS members on the panel is being considered. The two divisions are conferring on the matter, and the goal of addressing metrics will also be incorporated by APD. Dr. Green noted that PSD had been considering a study before the Fisk report came out, as part of a natural process. Dr. Greeley added that the PSS is planning to solicit input from the broad planetary community.

PSS reviewed ISS utilization for Planetary Science, and concluded that rigorous peer review and cost/benefit analysis will be needed before any concepts are considered. The stability of the microgravity environment at ISS is considered non-ideal for most planetary experiments. Some mission concepts were considered however, including experimentation in a radiation environment; raising the TRLs of planetary instruments; planetary sample acquisition, storage and handling technologies in low-gravity, cold environments; deployment technologies such as inflatable antennas; and potential as a receiving station for extraterrestrial samples to address backward contamination (this latter concept is generally considered not viable).

Dr. Greeley extended an invitation to an exhibit celebrating the 400th anniversary of Galileo's discovery of the Outer Planets at the Rayburn Building, to be held that week.

Recent PSS findings and recommendations were not intended for the NAC. PSS found that the LEAG is jointly chartered with ESMD, and it would be appropriate to add SBAG to the charter. PSS therefore recommends that SBAG be added to the charter in order to provide relevant scientific input, given the shift in direction of ESMD. Dr. Hinners, citing his experience with the Mars Exploration Program Analysis Group (MEPAG), suggested that a better model would be to include AGs on a task basis, to avoid the confusion of many AGs. Dr. Huntress felt there would be room for several ideas, and recommended keeping them under consideration until the human space flight program had settled down.

PSS found that the Astrobiology Institute demonstrated success in bring disciplines together, and considered the parallel body, the NASA Lunar Science Institute had planned its "CAN" for the next iteration in early FY11. PSS recommends that the CAN be delayed until the Decadal Survey can be digested.

Dr. Greeley provided some recent science highlights from the PSD. Cassini results indicate that the Saturn orbital eccentricity drives an uneven distribution of lakes on Titan, analogous to the forces that drive glacial/interglacial periods associated with Earth's axial precession. MRO data suggest that there may be glaciers on Mars. MRO is providing several lines of evidence for water-ice at mid-latitudes, including one image that appears to be a glacial land form. MRO has also discovered and characterized more than 100 new impact sites on Mars (impacts that have occurred within a months-to-years time period). This new image data, featuring unprecedented resolution, will refine the ability to determine ages of planetary surface features. Mars Express has also provided composite images of Phobos that will be used to determine potential Phobos-Grunt sample-return sites, for a Russian mission currently planned for 2011.

Dr. James Green continued the presentation with more science highlights, citing the Rosetta mission encounter with the Lutetia asteroid, a Main Belt asteroid. Lutetia possesses the characteristics of a carbonaceous chondrite and a hydrated mineral, an unusual type that may not have a meteoritic analog.

Lutetia is the largest asteroid observed from a fly-by, and has a complex morphology similar to that of Phobos. NASA is in the process of cataloging NEOs of 1 km and larger (about 950 found thus far). Any object of 5-6 km or larger is considered a planetary extinction event producer. A total of 6000 NEOs are being considered for human exploration. In the 2025 time frame, NASA is considering traveling to smaller NEOs, but at present does not have the tools to carry out an extensive search; there may be on the order of 60,000-100,000 such objects.

Hayabusa, a Japanese technology demonstration mission launched in 2003 with some NASA participation, successfully rendezvoused with comet Itokawa for a sample retrieval attempt. The spacecraft returned to Earth 13 June. NASA contributed navigation and Deep Space Network (DSN) tracking, sample analysis expertise, and a DC-8 observation team for re-entry. Initial indications are that some sample had been retrieved; NASA will obtain 10 percent of the sample.

Three PSD missions, Juno, GRAIL, and MSL are all planned for launch in August, September and November 2011, respectively. Recent PSD accomplishments of note include completion of a plan to restart domestic production of Pu-238, which has been delivered to Congress. NASA will need a budget and initiative from Congress to move forward on this plan. NASA's Trace Gas Orbiter (Mars 2016) instrument selection is on track for August 2010, and Discovery proposals are due September 3, 2010. Upcoming events include fly-bys of comets Hartley II and Tempel 1, insertion of the MESSENGER spacecraft into orbit around Mercury, the Dawn mission's rendezvous with the asteroid Vesta in July 2011, and the arrival of the Mars rover Opportunity at the precipice of the Endeavor crater.

SMD Interaction with OCT

Mr. Michael Moore presented an update on the coordination between SMD and the Office of the Chief Technologist on innovation and technology activities, emphasizing that OCT is still in a holding pattern pending FY11 budget approval.

SMD invests over $500M in technology development via four major avenues: mission-specific activities and focused technology development; individual PI-led research; suborbital research programs; and the Earth Science technology program. Technology development options in SMD largely rely on R&A programs for low-TRL technologies, enabling technologies for future missions, and limited cross-cutting technology development. SMD integration with OCT includes an identified point of contact, direct communication between the SMD AA and Chief Technologist, as well as chief technologists located at each NASA center. A NASA Technology Executive Council (membership includes the mission directorate AAs) and Center Technology Council (center representatives) have also been formed to help coordinate activities.

OCT divisions and programs include the Early Stage Innovation Division, Game Changing Technology Division, and Cross-Cutting Capability Demonstrations Division. SMD has had substantial direct input into SBIR/STTR, Center Innovation Fund Program and Technology Demonstration programs. SMD investments at centers will benefit from the ability of the OCT to coordinate activities of common interest. Strategic integration will occur via an upcoming roadmapping activity; it will be important for SMD to engage in Roadmap development and participants have already been identified. The intent is to have the roadmap reviewed by the NRC. In summary, SMD is coordinating with and supporting OCT effort to improve NASA capabilities in science and technology development, in addition to its own mission-focused technology development.

Dr. Hinners inquired where flight demonstration technologies resided within OCT. Mr. Moore replied that these were covered under Cross-cutting Capability Demonstrations. Dr. Hinners remarked that new technology incorporated over the decades has worked well, but he felt that technology demonstrations

typically provided a low return on investment; the new technology should be useful beyond a mere technology demonstration value. Mr. Moore expected that the executive councils would discuss this matter. Dr. Boss asked if science money was always required for OCT participation. Mr. Moore indicated that the OCT would expect a 25 percent contribution where applicable. Dr. Weiler reiterated that any SMD monies would be in the form of peer-reviewed competition. Committee members called for interaction within the NAC technology group in order to provide appropriate advice for OCT, noting that stovepiping would be counterproductive.

Public comment period
None noted.

Discussion
The Science Committee considered compiling Lessons learned on successful missions from existing databases at the Goddard Space Flight Center and possibly the Jet Propulsion Laboratory. Dr. Weiler tasked Dr. Feeley to query relevant parties at the next staff meeting in order to identify program managers and PIs of successful missions, while also addressing the Sega report. The Science Committee also requested that SMD, via Dr. Feeley, provide information on cost overrun data grouped in the category of PDR to end of mission, as well as how much money had been invested in Phases A and B.

Findings and Recommendations to take to NAC
No formal recommendations were carried from HPS, PSS and APS. The Science Committee agreed to carry a recommendation from ESS regarding data quality and scope for polar satellites. The committee also carried three PPS recommendations as previously described [two of these PPS recommendations were later withdrawn].

Appendix A
Attendees

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

NASA Attendees
James Adams, NASA Headquarters
Marc Allen, NASA Headquarters
Dwayne Brown, NASA Headquarters
Catharine Conley, NASA Headquarters
Matthew Dolloff, NASA Headquarters
Kristen Erickson, NASA Headquarters
Chris Flaherty, NASA Headquarters
Richard Fisher, NASA Headquarters
Michael Freilich, NASA Headquarters
James Green, NASA Headquarters
Lika Guhathakurta, NASA Headquarters
Hashima Hasan, NASA Headquarters
W. Vernon Jones, NASA Headquarters
John LaBrecque, NASA Headquarters
Thierry Lanz, NASA Headquarters
Lia LaPiana, NASA Headquarters
David Leisawitz, NASA Headquarters
Michael Moore, NASA Headquarters
Jon Morse, NASA Headquarters
Douglas McCuistion, NASA Headquarters
Melissa McGrath, NASA Marshall
Michael New, NASA Headquarters
Marian Norris, NASA Headquarters
Adriana Ocampo, NASA Headquarters
Arik Posner, NASA Headquarters
Andrea Razzaghi, NASA Headquarters
Mike Reddy, NASA Headquarters
Michael Seablom, NASA Headquarters
James Slavin, NASA Goddard
Linda Sparke, NASA Headquarters
Ray Taylor, NASA Headquarters
Stephen Volz, NASA Headquarters

Ed Weiler, NASA Headquarters
Greg Williams, NASA Headquarters
Dan Woods, NASA Headquarters
Geoff Yoder, NASA Headquarters

Non-NASA Attendees
Linda Billings, George Washington University
Francesco Bordi, Aerospace Corporation
Doug Britt, Dynamac Corporation
Dom Conte, Orbital
Randy Correll, Ball Aerospace
Walt Falconer, Strategic Space Solutions
Caroline Trupp Gil, American Chemical Society
Amy Klamper, Space News
Donald Kniffen, USRA
Jon Malay, Lockheed Martin
Steven Merkowitz, Office of Science and Technology Policy
Larry Richardson, United Launch Alliance
Garrett Saito, Lewis Burke Associates
Daniel Williams, Jr., Ball Aerospace
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
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 Hinners
Consultant
Littleton, Colorado

‡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

Note:
‡ = *ex officio* member

Appendix C
Presentations

1. Science Mission Directorate Update, *Edward Weiler*
2. Controlling Cost Growth of NASA Earth and Space Science Missions, *Ronald Sega*
3. Heliophysics Division Update, *Roy Torbert and Richard Fisher*
4. Earth Science Division Update, *Byron Tapley and Michael Freilich*
5. Exploration Systems Mission Directorate Status, *Douglas Cooke*
6. Astrophysics Division Update, *Alan Boss and John Morse*
7. James Webb Space Telescope Progress Report, *Jon Morse*
8. Planetary Protection Subcommittee, *Eugene Levy*
9. Planetary Protection at NASA, *Cassie Conley*
10. Planetary Science Division, *Ronald Greeley and James Green*
11. SMD Interaction with the Office of the Chief Technologist, *Michael Moore*

Appendix D
Agenda

July 13-14, 2010
NASA Headquarters, MIC-3 (3H46)

Day 1 (Tuesday, July 13) in MIC-3

8:30-8:40am	Remarks and Announcements	Huntress, Feeley
8:40-9:40am	Budget Update/Q&A with SMD AA	Weiler
9:40-9:50am	**Break**	
9:50-10:25am	NRC Study on Cost Growth in SMD Missions	Sega
10:25-10:45am	Discussion	
10:45-11:30am	Heliophysics	Torbert, Fisher
11:30-Noon	Discussion	
Noon-1pm	**Lunch on Own**	
1:00-1:45pm	Earth Science	Tapley, Freilich
1:45-2:15pm	Discussion	
2:15-2:45pm	ESMD Planning & ESMD-SMD Cooperation	Cooke
2:45-3:15pm	Discussion	
3:15-3:30pm	**Break**	
3:30-4:15pm	Astrophysics	Boss, Morse
4:15-4:45pm	JWST Progress Report	Morse
4:45-5:15pm	Discussion	
5:15 pm	**Adjourn**	

NAC Science Committee
July 13-14, 2010
NASA Headquarters, MIC-3 (3H46)

Agenda (Cont'd)

Day 2 (Wednesday, July 14) in MIC-3

8:30-8:45am	Remarks and Announcements	Huntress, Feeley
8:45-9:30am	Planetary Protection	Levy, Conley
9:30-10:00am	Discussion	
10:00-10:15am	**Break**	
10:15-11:00am	Planetary Science	Greeley, Green
11:00-11:30am	Discussion	
11:30-Noon	SMD's Interaction with OCT	Moore
Noon-12:15	Discussion	
12:15 – 1:15pm	**Lunch on Own**	
1:15-1:30pm	Public Comment	
1:30-2:30pm	Findings and Recommendations	
2:30-2:40pm	Final comments/Wrap-up	
2:40pm	**Adjourn**	