

# NASA ADVISORY COUNCIL

## SCIENCE COMMITTEE

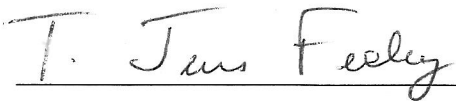
November 14-15, 2012

NASA Headquarters  
Washington, D.C.

### MEETING REPORT



Wesley T. Huntress, Chair



---

T. Jens Feeley, Executive Secretary

*Table of Contents*

Welcome and Introduction	3
Curiosity Update	4
Planetary Science Update	4
SMD Civil Service Workforce History	7
Joint Session Human Exploration and Operations Committee (HEOC)/Science Committee	7
Mars Program Planning Group	7
PPS Status	10
JWST Status	11
Heliophysics Update	12
Astrophysics Update	14
Earth Sciences Update	16
Public comment period	18
Discussion	18
Meeting with SMD AA	18
Findings and Recommendations	19

*Appendix A- Attendees*

*Appendix B- Membership roster*

*Appendix C- Presentations*

*Appendix D- Agenda*

***Prepared by Joan M. Zimmermann  
Zantech, Inc.***

November 14, 2012

Welcome and Introduction

Dr. T. Jens Feeley, Executive Secretary of the NASA Advisory Council (NAC) Science Committee opened the meeting and noted that the usual Federal Register notification had been late in being published and reported that a constructive effort had been made to notify those who normally participate to enable them to attend the meeting and/or participate by Webex. Procedures have been put in place to prevent this from happening again.

Dr. Wesley Huntress, Chair of the NAC Science Committee addressed the membership, and thanked Dr. David McComas for standing in during the summer meeting of the NAC. He praised the success of the Mars Science Laboratory (MSL), but noted serious issues with the proposed budget for the Planetary Science Division (PSD) and the current fiscal situation. In the science arena, however, there is much to be pleased about.

Curiosity Status and Update

Dr. Michael Meyer presented a status of the MSL Curiosity Rover, which has the potential to answer questions about the origin and evolution of the universe, through its analysis of ancient rocks holding a record of evidence dating back to the early epochs of Mars. The mission has been transmitting 400Mb data/day. As MSL goes forward, the Mars Exploration Program (MEP) is continuing its integrated program. The rover Opportunity still going strong, and may be able to touch clay before Curiosity does. The aeronomy mission MAVEN is scheduled to launch in November 2013.

On Curiosity there are 10 instruments: There are four categories of instruments: the remote sensing instruments Mastcam (Mast Camera), ChemCam (laser-induced breakdown spectroscopy Laser-Induced Breakdown Spectroscopy for Chemistry and Microimaging) located on the remote sensing mast, and MARDI (Mars Descent Imager); the contact science instruments APXS (Alpha Particle X-ray Spectrometer) and MAHLI (Mars Hand Lens Imager) located on the end of the robotic arm; the analytical laboratory instruments CheMin (Chemistry and Mineralogy) and SAM (Sample Analysis at Mars) located inside the rover body; and the environmental instruments RAD (Radiation Assessment Detector), DAN (Dynamic Albedo of Neutrons) and, REMS (Rover Environmental Monitoring Station).

During the cruise phase, the RAD instrument received data, showed particle counts, measured galactic cosmic rays, and collected data on solar energetic particle events. MSL has substantially reduced the margin of error in landing ellipses, enabling future missions to target exploration of interesting areas that are harder to reach. It has also shown that hazard avoidance through imaging will also be possible in the future. Dr. Meyer displayed numerous images from the mission.

ChemCam has analyzed rock targets such as Coronation and Beechey. APX data taken from the Jake Matjevic rock has revealed it to be basalt. APX can analyze any target within 7 meters; the laser fires quickly, 50 shots within a couple of seconds. The drill has not yet been used, but MSL has sampled surface soil. Ground and air temperatures vary within a range of 90°C. Diurnal pressure changes have been seen, largely an effect from the extreme daily heating and cooling, and possibly a product of site topography. The DAN instrument has been obtaining measurements of hydrogen within the first meter of soil.

Curiosity's initial destination, called Glenelg, is at the meeting of three main geological features: an alluvial fan, a hummocky unit, and a cratered unit. High thermal inertia is also a feature of the target.

Conglomerates that imply the presence of an ancient riverbed have been imaged at sites such as “Hottah.” Asked how decisions to release data were reached, Dr. Meyer reported that preliminary data are presented to the science team, which is then evaluated for about a week before public release.

The SAM suite has 54 valves, and 52 heaters. The instrument uses tunable lasers that will yield data on isotopes and trace gases. Thus far the presence of carbon dioxide, argon, nitrogen, etc. has confirmed the composition of Mars meteorites found on Earth. Analysis completed to date implies that Mars has lost a good portion of its atmosphere over the millennia. Rocknest results are still being evaluated; the science team hopes to have results by the American Geophysical Union (AGU) meeting date in early December. The two-dimensional x-ray diffraction currently used on MSL is also now available in field suites that are being used to verify antiquities (e.g., King Tut’s tomb) as well as malarial drugs in Africa, about 50% of which are counterfeit. Detection of methane thus far has been in the 1 plus or minus 3 ppb range, considered a non-detection. There will be an opportunity to make more precise measurements over the next 6 months to confirm whether this result is a true non-detection of methane. MSL will take measurements of the atmosphere about once a month.

The Curiosity landing event captured one-third of all the page hits on NASA sites over the past 8 years, constituting 36.4M individuals. JPL is producing animations, such as “Mars in a Minute,” and will be creating more over time. Curiosity continues to make progress toward Yellowknife Bay, a lowland near Glenelg, where it will sample stratigraphy and take panoramic photos as it makes its way to Mt. Sharp over the next year.

Dr. McComas asked how the program decided to release its public announcements, noting that in Heliophysics, a published paper usually precedes an announcement. Dr. Meyer acknowledged that it is a challenge, and the program is making an effort to keep the public engaged. All images are on the Web within 24 hours. Eventually, the synthesis of data will lead to papers that deal with more comprehensive measurements involving multiple instruments. There are 420 scientists associated with MSL, who among them contribute to the decision-making process. The Project Scientist group (9 PIs), and NASA program managers (PMs) help to coordinate results. Asked how the team deals with dissent, Dr. Meyer explained that non-consensus opinions generally come out in the second wave of publications. Dr. Eugene Levy noted that this process is not unusual; the Hadron Collider works this way, providing a good way to observe new protocols associated with large groups.

### Planetary Science Update

Dr. Janet Luhmann, chair of the Planetary Science Subcommittee (PSS), addressed other planetary activities beyond MSL, and stressed the importance of thinking ahead in planetary science. In its last meeting, PSS heard Europa mission study results via a presentation from David Senske and the Europa Science Definition Team (SDT), reflecting an effort to produce a reasonably affordable Europa mission that would satisfy Decadal Survey elements. Europa is believed to have an internal ocean and to harbor elements of astrobiological import. Goals of exploration would be to study the interior “life of water” at Europa, and the chemistry and geology of icy satellites. A solar-powered “Clipper” mission was singled out as a feasible mission, for roughly \$1.98 B. The study results were blessed by the Outer Planets Analysis Group (OPAG) and SDT as the best science per dollar. The technical concept is regarded as mature and implementable within the identified cost target. However, because there are restrictions on new starts within PSD, the mission cannot be initiated. The study team will deliver final reports by the end of December. Dr. Bradley Peterson asked what feature made the Clipper mission stand out. Dr. James Green, Director of the PSD, indicated that in the radiation environment of Europa, any mission has a limited lifetime; with its multiple flybys the Clipper mission concept would minimize the time it spends in the heavy radiation regions. The Clipper would orbit Jupiter and visit Europa for reconnaissance

flybys. In-house cost estimates and independent estimates were instrumental in determining mission cost, noted Dr. Green.

InSight, or Interior Exploration using Seismic Investigations, Geodesy and Heat Transport, is the most recent Discovery selection. The main instruments are being provided by a number of partner space agencies. InSight will determine the size, composition, and physical state of the Mars core, thickness and structure of crust, and the current rate of meteorite impacts on Mars. The mission design includes a simple payload, comprised of a single seismograph that will be set on the surface. Heat flow will be measured by an innovative self-penetrating mole. InSight will be a Phoenix-style mission, using airbags to land in the western portion of Elysia Planitium. The seismometer will be protected from the environment to avoid interference with signal. InSight is due to launch in early 2016, landing at Mars in late 2016, to begin a 720-day mission, ending in September 2018. MAVEN, the final Mars Scout mission, remains on track in schedule and cost. MAVEN will measure the details of the upper atmosphere of Mars, to determine the importance of escape in its dynamics. Instruments are scheduled to be delivered in Fall and Winter 2012 for a launch in November 2013.

PSS was very encouraged to hear that the Mars Program Planning Group (MPPG), a Mars-replanning effort led by Orlando Figueroa, has retained the science priorities of the Decadal Survey, and is encouraged by preliminary Congressional actions to restore funding to the Mars Program. PSS was also updated on the New Frontiers OSIRIS-Rex program, a sample return mission to a carbonaceous asteroid, which is due for launch in 2017, a seven-year mission from launch to return. The mission will include IR spectroscopy, thermal emission, and x-ray imaging spectrometry measurements. The mission will utilize a touch-and-go sampling scheme; the sample collection device uses nitrogen gas to blow regolith into a collection chamber, representing a technically challenging and new way to sample regolith. A contest is ongoing to name the asteroid; its current name is 1999-RQ36.

PSS was also pleased to hear about NASA's decision to participate in the European JUICE mission to Ganymede, Callisto and Europa, providing \$100M in support of the mission through a joint-selection scenario. While mission design is still in progress, it is expected to include spectroscopy, in situ fields and particles, etc. Launch is scheduled for June 2022; it will include a 7.6-year interplanetary transfer and will be solar-powered.

PSS also reviewed a recently identified MERcury Surface, Space ENvironment, GEOchemistry and Ranging (MESSENGER) issue; the craft has adequate fuel for an extended mission but was not considered by the Senior Review process for continuation; as Mercury has no Analysis Group for advocacy and visibility, PSS sought to bring the matter forward to the Science Committee for consideration. MESSENGER will have the opportunity to make some observations during a solar maximum.

### ***Planetary Workforce Survey***

Dr. Luhmann reviewed Dr. Frances Bagenal's recently completed effort to survey the demographic features of the planetary science community, a community with few practical sources of funding outside of NASA. The survey was largely of academic departments and scientists belonging to the American Geophysical Union (AGU), the American Astronomical Society's Division of Planetary Science (DPS) and participants at the annual Lunar and Planetary Science Conference (LPSC). Results of the survey are available online. The survey found that planetary scientists comprise a unique community that relies on NASA support and soft money. Fifty-three percent of the community is supported by NASA funding only, and 68% by NASA and NSF combined. Other questions to be addressed in future surveys are the numbers of undergraduate and graduate students from major universities, as well as employer opinions of the workforce. Other concerns are the loss of top candidates due to the non-lucrative nature of the

discipline. PSS also heard an overview on the new National Research Council (NRC)-CAPS (Committee on Astrobiology and Planetary Science).

### ***PSS Concerns***

PSS raised concerns about the reduction in the PSD budget, particularly as the pipeline of new missions is nearly empty. The Mars Program budget has been reduced by 35 percent, and the apparent non-implementation of Decadal Survey proposal's call for enhanced Discovery and New Frontiers mission cadences are of high concern to the community. Notwithstanding, PSS felt MPPG did an excellent job in revisiting the program, and that the Europa re-scoping mission "Clipper" study was well done. PSS supports restoration of funding to Astrobiology, citing successes from this program that have generated great interest among students and the public. General concerns remained from PSS's previous meeting, i.e. the distressing impact of the budget, the delayed next Discovery AO and selection, the canceled ExoMars mission participation, the lack of NASA plans beyond 'study' status of recommended Europa and Mars missions, underfunded and always threatened research and analysis (R&A) programs, the fate of future NASA "Institutes," plutonium and Advanced Stirling Radioisotope Generator (ASRG) availability for future outer solar system mission proposals within Discovery and New Frontiers, and a lack of clarity on procedures for funding private enterprise missions such as B612 (asteroid survey and hazard assessment by a private company).

Dr. Green presented the status of the PSD, and provided some updated Division responses to PSS recommendations and findings. The Division is currently developing a strategy for response to the next budget submission; the next Discovery and New Frontiers selections are currently planned for 2015 and 2016, respectively; future Mars mission selections are to be decided. There is no new money at present for new flagship missions. PSD has made steady progress in increasing funding for R&A, reaching a total of \$244M in 2012. Commitment to R&A remains strong and the goal is to keep the annual funding levels between \$220 and \$240M. There have been some higher-dollar awards and increased length of grant periods to 4 years in some cases, and there will be a renewed effort in FY13 to release selection results one month after the peer review panel convenes. An extended mission proposal for MESSENGER is now in progress. With regard to the plutonium restart, NASA has worked hard with the Department of Energy (DOE), resulting in some significant milestones. In August, a sample of neptunium-237 was irradiated at Oak Ridge National Laboratories, generating a qualified Pu-238 product in September. NASA is now generating a project plan to scale up to produce 1.5 to 2 kg plutonium-238 per year; the project baseline and confirmation will be developed by December 2013. The effort will take between \$70-90M to initiate and continue. ASRG development is also underway; the Division is working to identify the next ASRG mission, and will have 2 flight units completed by 2016. The 2016 date is being provided an additional slack of 6 months in schedule. Cooperation between DOE and NASA is going well, despite some past communication and management issues. NASA holds a quarterly management review with DOE, which helps to track progress and provides insight into maintaining the schedule.

Opportunities in 2013 include the launch of the LADEE lunar dust mission from NASA's Wallops Island facility; a flyby of Earth by the Juno spacecraft; the launch of MAVEN; and the sighting of the comet ISON, which has been estimated to be the "comet of a lifetime." Its closest approach to Earth occurs in January 2013. Public engagement activity is being performed as it had with the Venus Transit activity. NASA logged 614M web hits for the Transit event. Dr. Green displayed the video challenge results- (winners posted at [tongal.com/project/NASA](http://tongal.com/project/NASA)). In other public engagement endeavors, NASA held a conference at Headquarters to celebrate fifty years of Solar System exploration, marking the fiftieth anniversary of the first planetary mission, the Mariner spacecraft to Venus.

### SMD Civil Service Workforce History

Mr. Roy Maizel presented a status and history of the Science Mission Directorate (SMD) workforce. He noted that at the point of the Office of Earth Science and Office of Space Science merger in 2004 to form SMD, there were 221 employees. Four transfers of work also occurred in the ensuing period. Currently there is a ceiling of 150 employees for SMD; with 142 civil servants currently employed by SMD. This represents a 35% reduction since 2004. The total NASA workforce has been reduced by 3% and the Headquarters (HQ) workforce by 12%. About half of this reduction occurred early in 2004 and 2005. A temporary merger of the Earth Science Division (ESD) and the Heliophysics Division (HPD) was attempted and failed. Administrative support was also greatly reduced, along with some reductions of work; however, this reduction included some loss of Integrated Program Office (IPO) functions. There has been a dramatic increase in reporting activities to the Office of Management and Budget (OMB) and Congress, with respect to status of mission costs and schedules. There has been an increase in audits from the Office of the Inspector General (OIG) and the General Accountability Office (GAO), which encumbers HQ and Center time. There are more internal reporting requirements as well, as the Agency now conducts joint estimates at Key Decision Points (KDPs). Over half the work force at SMD are Program Scientists and Executives. As of 6 November, SMD had 10 IPAs and 28 detailees, more than 25% of the SMD ceiling. IPAs (intergovernmental personnel) are more expensive, they lack continuity and institutional memory, and they may possess a potential home institution bias. SMD supports an active detailee program, but too great a reliance on detailees can lead to a lack of stability. A fully loaded civil servant at the GS-15 level costs about \$170-180k per year, an IPA \$210-215k per year. All civil servants are paid out of AMO (Agency and Management Operations). IPAs and detailees are paid out of SMD funds. There are currently 15 contractors at SMD. At the end of 2011, NASA lost a large amount of its secretarial workforce, and has been filling many of these slots with contractors. The Agency is also using contractors to carry out some Program/Project cost estimation functions. SMD is conducting a pilot program using a contractor to perform selected functions of a Program Officer (PO)/discipline scientist.

The average age of an SMD employee is 53; 21% of the SMD workforce could retire today. An additional 28% of the workforce is eligible for a potential "early out" retirement at ages 50-55. Only 8% of the SMD workforce is under 40. In addition, the HQ building is being reconfigured, and SMD will eventually occupy the third floor. A total of 230 spaces will be available, which will form the grand total for the ceiling of SMD. There is relentless pressure on AMO that makes relief unlikely. The AMO supported an HQ ceiling of 1213 employees in FY12, which will decrease to 1190 full-time equivalents (FTEs) per year thereafter. Dr. Luhmann asked if there were more effective ways to ameliorate the situation, such as through the use of remote IPAs. Dr. Feeley commented that as a rule, IPAs are usually within the community at HQ. Dr. Max Bernstein cited a detailee from Goddard Space Flight Center (GSFC) as another example. Mr. Maizel felt that remote employees would be worth considering with the rise of telecommuting. Thirty percent of employees at HQ are at mission directorates. The total for HEO is very comparable- within the noise level, it has the same number of civil servants. There have been proportionate reductions for other mission directorates since 2004, as well.

### Joint Session Human Exploration and Operations Committee (HEOC)/Science Committee

#### Mars Program Planning Group (MPPG)

Dr. James Garvin presented a summary of the final report of the Mars Program Planning Group (MPPG), an *ad hoc* group that had been created to address Mars program budgetary changes, the 2011 Decadal Survey, and Presidential language directing NASA to land humans on Mars in the 2030s. MPPG's core team was represented by scientists, NASA program managers, and others who had worked on the Mars program for the past 20 years. MPPG was informed by many groups, including NASA advisory subcommittees. Its charter was to provide Mars mission options that were credible in terms of budget,

collaboration between HEO, the Office of the Chief Technologist (OCT) and SMD, and guided by the Decadal Survey as well as the external scientific community. Opportunities for 2018 and 2020 missions were considered; given that 2018 is a more favorable opportunity in terms of orbital dynamics. The point of departure was the Mars 2000 Plan; MPPG retained key features of the highly resilient and successful Mars 2000 program. Answering a question from HEO, Dr. Garvin noted that the group had considered the most recent Life and Physical Sciences Decadal Survey considered with high intention but less direction.

Over the next 15 years, the Mars program will move toward broader capabilities overlapping in SMD, OCT and the HEOMD. MPPG explored many options while evaluating a common goal, based on a Mars sample return architecture. The Mars exploration strategy of the last decade has yielded extraordinary scientific output, using discovery-driven scientific pathways. The Mars exploration program has had and should have both strategic and stand-alone missions. MPPG utilized a traceability matrix to evaluate candidate pathways, including missions and goals recommended by the Decadal Survey and the Mars Exploration Program Analysis Group (MEPAG), as well as risk postures associated with each pathway. Sample return is considered the best pathway in terms of scientific return, risk, available and mature technologies, pace of funding, and infrastructure investment. Given the current knowledge of the Solar System and known conditions for life on Earth, MPPG concluded that one must study multiple sites to find signatures of life.

A workshop was held at the Lunar and Planetary Institute (LPI) to consider the known recommendations of the Decadal Survey and discuss Mars approaches for Mars exploration, including sample return and sampling of Phobos and Deimos. The workshop expanded the trade space for concepts to access the Mars surface, sampling and analytic instruments, surface system capabilities, including SEP orbiters to return samples to Earth, astronaut-mediated sample return, smallsats, etc. Collaboration between the three directorates for a long-term goal of putting humans at Mars in 2033+ must mitigate risks for the in-space segment of the mission, understanding risk to crews, etc. Capabilities, requirements and opportunities for such goals were identified and divided into a rough schedule: epoch of first use in 2012-24; large propulsive stage, deep space habitat for 2024-2033; followed by SLS upgrade, advanced propulsion, deep space habitat (900 days +) for 2033+. This approach would build up system capabilities while gaining deep space operations experience and reducing risk as exploration reaches farther out.

A participant from HEO asked whether the MPPG had hewed to the President's original directive. Dr. Garvin responded that MPPG has merely suggested that 2033 be used as an anchor date, a concept that is supported by studies in the final report. The HEO member felt that a plan to put a crew on the surface of Mars goes beyond the President's vision. Answering the question of whether there is value of having humans in orbit at Mars without going to the surface, Dr. Garvin pointed out that the MEPAG had concluded that the entire 90-day Opportunity mission could have been done in one extravehicular activity (EVA). Dr. Peterson commented that one might make an argument that astronauts orbiting Mars could instruct robots on the surface of the planet.

MPPG has advocated an approach that will transition clean interface collaboration to interdependent collaboration. Joint activities will be associated with greater capabilities. Opportunities for collaboration among OCT, HEO and SMD include science-focused missions to fill strategic knowledge gaps (SKGs), increase communication capabilities, improve navigation, and support advances in propulsion and aerocapture, etc. Ideas include HEO measurement options on robotic missions, or a 2024+ single-shot Mars sample return mission on a Space Launch System (SLS) vehicle, which may be provided by launch cadence and availability. Another idea is to "break the chain" of sample return by grabbing a Mars sample in Earth orbit via the Orion vehicle; a crew entry system would eliminate the need for a robotic Earth-entry system.



MPPG mapped out near- and long-term opportunities to open the Mars frontier, with cross-benefits across NASA. Concepts include optical communications demonstrations, deep-space atomic clock demonstrations for precision navigation and entry, descent and landing (EDL), in situ resource utilization (ISRU), and sample handling, forging the opportunities based on budgets. MPPG also identified key technologies for EDL, ISRU, and Mars ascent, as well as three key functions for Mars Sample Return (MSR): infrastructure, sampling, and retrieval/return. Sample return launch options include three launches that separate sampling and caching; a two-launch mission concept; and a one-launch mission that deposits a sampling rover carrying a Mars Ascent Vehicle (MAV); all considered within the context of pathways. Sampling rover concepts were also studied, including cost estimates. Cost analyses also considered moving launches from 2018 to 2020. Four options were considered for rover design. Rover A is a MER clone; Rover B is a higher-volume Rover A; Rover C is an MSL-derived design; and Rover D is a rover with an integrated MAV. The sample mass considered is in the sub-kilogram range, as mass is constrained by the budget. Rover concepts included cost estimates as well; Rover C is estimated to cost \$1.3 to 1.7B. An estimate for Rover D is ongoing. Phase E is not included in the cost estimates. Launch vehicle costs are based on Falcon 9 or Atlas V data from the NASA Launch Services Office, derived from the most recent NASA Launch Services (NLS II) contract.

Orbiters considered by the MPPG included telesat (relay)-only; traditional science and relay orbiters; sample-return orbiters; and round-trip science and sample return. Dr. Luhmann commented that the MPPG seems to have ignored international efforts. Dr. Garvin noted that the group did have discussions with the EU, concluding that exoMars would have to have its orbit moved; moreover the Europeans have not built their mission for long-life. A number of orbiter concepts were considered, including one that is relay-only, as well as a combination of traditional science and relay orbiters; solar electric propulsion (SEP) sample-return schemes; and round-trip sample return with both science and relay orbiters. MPPG also considered the effects of the aging infrastructure at Mars.

Cost analysis processes used methods that were graded as gold standard (ICE and CATE); silver (parametric); and bronze (educated estimate). Sample missions for 2018-24 were presented, along with their estimate standards. The best estimates thus far have been obtained for the Rover C concept, and for a communications/high-resolution camera/mineral mapper orbiter. An “athlete” rover is being studied at JPL. The Mars Curiosity rover, by comparison, has cost \$2.65B. An orbiter in 2018 would provide infrastructure to all landed missions in 2020-26. However, the President’s budget runout does not support a rover in 2018 (without an augmentation); the budget does support a Rover B concept in 2020 under current budget conditions. Sample options for strategic collaboration were diagrammed, and costs and risks were assessed in terms of science, SKGs, and other relevant parameters. MPPG reached out to the international community, but only peripherally. Commercial entities were also consulted, and the group also considered R&A within the context of collaboration. In summary, the MPPG options represent a savings of 50% compared to Decadal Survey concepts.

Dr. Huntress asked how the MPPG results would be implemented and which pathway would be most valuable for human exploration. Dr. Garvin responded that the MPPG provided information meant as a toolkit for use by NASA. The decision space is now with the MEPAG and senior management. For human space flight, the first step is for HEO to develop Orion, SLS, and a launch vehicle with an energetic upper stage. This would take the program through the mid-2020s. Other optimizations are at the experiment/technology level. To maximize HEO, one opportunity might be a 2018/20 mobile lander, with measurement of radiation, and technologies that allow greater entry masses (e.g., inflatables). Asked if there were a traceability matrix for justifying humans on Mars, Dr. Garvin indicated that MPPG accepted previous work from MEPAG on this issue. Dr. Byron Tapley commented that the program would need an equivalent assessment of science benefits relative to having humans at Mars. Noting that there are two appropriations bills adding roughly \$100M for the Mars program, Dr. Garvin reported that the MPPG

feels it would be a good infusion to reduce risk for a rover in the Spirit/Opportunity class for the 2018 opportunity; it is a question for the community to assign value to this concept. Asked if lunar astronauts had been involved in discussing the human-in-orbit vs. human on surface options, Dr. Garvin noted that it they had not been involved, but had been part of the discussion under the previous administration. Human exploration concentrates more on survival than science return. Teleoperability is much more able than that on offer in the lunar era- the next step is to consult lunar era astronauts on more practical applications. As on Earth, Mars sample return is never done. However robots can enhance the trade space of humans at Mars. In terms of planning flexibility, MSL has the potential to change the game, and there is the danger of programming Mars exploration into a channel. Reacting to discoveries will take time, no matter what is found; a surface mission to sample an exciting site would be one reaction to discovery. If everything we know is wrong, then perhaps an orbiter would be more appropriate. In the end, it collapses down to a couple of cases; the value of picking apart a sample on Earth is incalculable. MSL will help educate researchers further on what is at Mars. JPL is looking at many possibilities, such as a mobile MAV.

An HEO member commented that think it would require \$100B or more to send humans to the Mars surface, if not more. Dr. Garvin agreed, adding that in 2004, Administrator Sean O'Keefe commissioned studies indicating costs at this level. Dr. Huntress asked if humans at Phobos/Deimos had been considered for sample return. Dr. Garvin replied that MPPG did not study this, although there have been previous studies on the concept. Humans interacting with these objects is considered too risky; the orbits of the moons are also not favorable. Dr. McComas commented that radiation data would have to be a primary input to assess the cost-risk space for human support, and asked if this data would be part of the follow-up. Dr. Garvin noted that the Precursor SAG (PSAG) had discussed radiation issues and that there is data that can be applied. Dr. Mike Wargo of HEO responded that the MPPG recognized the role of surface radiation measurements, and that there is now good and compelling data from both cruise and surface data from MSL; these data are primarily related to solar energetic particle (SEP) events, rather than galactic cosmic rays. In addition, members from the Space Radiation AG at Johnson Space Center have been engaged, and a pipeline has already been established to the human health community. Dr. Meyer commented that the first official data points from the cruise phase are being processed; the first data sets are due 6 months from acquisition. Dr. Luhmann noted that the MAVEN mission will have an SEP event detector that will provide information on particles up to 100 MeV. Dr. Wargo added that when capturing high-value science, future missions will also have the opportunity to fill SKGs; clearly HEO will leverage all the opportunities possible, both at NASA and in international missions. Dr. Garvin summarized the MPPG's goal as to help NASA in the transition period between robotic and human exploration, both for science and for understanding safety issues on Mars. Personally, Dr. Garvin felt there was a groundswell of support from SMD and HEO to partner on this issue. Dr. Luhmann noted that the risk factor will still have to be acceptable to the decision-makers and to the public at large, and feared that the risk acceptance will be hard to achieve. Referencing longer-term planning efforts, Dr. Garvin cited a 2000 Decadal Planning Team that studied 50-year horizons, and in 2004, some 25-year scenarios were developed; fidelity suffers the further out one goes. Dr. Huntress commented that a successful sample return would be necessary to further human exploration at Mars.

#### Report to NAC Science Committee from Planetary Protection Subcommittee

Dr. Levy, Chair of the Planetary Science Subcommittee (PPS) re-submitted a previous recommendation requesting that NASA implement a procedures document governing planetary protection requirements within human exploration. There are two broad areas of implication: substantive, which aims at reducing the risk of both forward and back contamination; and a public perception risk that NASA must be cognizant of. There are deep concerns in the public regarding the risk of contamination to the Earth.

At issue is the ability to control the transfer of organisms and spores. While the health of astronauts in

interplanetary missions is important, the real factor is the protection of the environment and of Earth. Dr. Levy cited NPD 8020.7G, Biological Contamination Control for Outbound and Inbound Planetary Spacecraft, which tasks the AA for HEOMD for this oversight. The PPS recommends that NASA develop an appropriate implementing document at a level corresponding to COSPAR's planetary protection policy and adopt it as soon as possible. The consequence of not acting positively on this recommendation is that NASA will be out of compliance with its own policy documents and with international agreements governing space exploration. PPS has also drafted a white paper on the subject to support this recommendation. Dr. McComas commented that there had been relatively broad support early in the discussion at the summer NAC meeting; however this was the only recommendation that did not go forward, and therefore the white paper was drawn up in response. Dr. Levy agreed to provide the white paper in advance of the next NAC meeting.

#### JWST Status

Mr. Geoff Yoder presented a status of the James Webb Space Telescope (JWST). The spacecraft bus critical design review (CDR) is impending. Much time and effort are going into the development of the telescope's multi-layered sun shield, antenna, and solar panels. The unfolding of the tennis-court-sized sun shield will take place over three days. As the sun shield can't be unfolded at cryogenic temperatures, the mission team is doing everything possible to reduce risks in Earth-based testing.

Recent progress includes the completion of the NIRCam (near-infrared camera) instrument's level cryogenic-vacuum test #1. Two issues are being worked in advance of test #2. The instrument is in the chamber now for testing in mid-November to validate fixes for stray light issues. The NIRCam schedule has delivery slipping past December 2012. The Canadian Space Agency fine guidance sensor (FGS)/NIR imager and Slitless Spectrograph has been delivered to Goddard Space Flight Center (GSFC). The NIRSpec instrument reassembly is complete; and completed primary mirror segments have begun to arrive at GSFC as well; a mass margin issue is being worked successfully and the project has a plan for reaching an appropriate margin by March 2013. The mission team held a technical interchange meeting with ArianeSpace and discussed an expansion of window opportunities in 2018. All initial baseline reviews have been completed for Northrop Grumman Aerospace Systems and all its subcontractors; only Exelis/ITT IBR remains to be reviewed. The mission is also developing a broad JWST messaging strategy for NASA and its partners.

Key watch areas remain the same: focus on executing task and focus on communication and education, ISIM cryovac tests, mass margins, schedule and critical paths, and workforce. No schedule has been lost and the mission is still maintaining its funded schedule reserve. Key items to work include mitigating risk to the critical path and are in progress. Some cryogenic testing patterns have been changed to account for instrument delays.

Recent instrument progress includes the MIRI instrument having been delivered to GSFC, and the NIRCam A and B modules to the Lockheed Martin test facility. With regard to optics, all mirrors are complete, and aft optics assembly (AOS) integration and testing are complete. Backplane wing production is on a six-day per week assembly operation schedule and is making good progress. The backplane support frame is also moving well, with bonding issues that do not affect the critical path. Updates are being made to the seam alignment of the sun shield, and catenary placement procedures to help offset effects of edge waves. The fold process is being tested now, and there will be tests on rolling and unrolling to further validate the process. A third-scale model is used for testing, and a full-scale model is used for validation. In terms of behavior at one g and zero g, third-scale models can be used in this case to predict how some components will behave in a zero g environment. Observed sunshield membrane material edge waviness is under investigation for a root cause, perhaps due to storage periods and aging. Dr. McComas asked if the sun shield could charge up; if the shield is electrically conductive,

this would solve the potential problem of spacecraft charging. Mr. Yoder agreed to provide an answer as to whether the sunshield is electrically conductive.

Chamber A ground support equipment (GSE) progress is being completed at Marshall Space Flight Center (MSFC). The Deep Space Edge Radiation Sink concept has been verified. The Science and Operations Center Program and Project Office met with the Space Telescope Institute Council for discussions on topics such as project status and messaging strategy. A list of events that will occur over the next 6 years has been compiled. The mission is also measuring performance and is actively looking at Earned Value Management (EVM), schedule health matrix, and technical milestones. For FY12 unallocated future expenses (UFE), encumbrances have been incorporated into the baseline, and the mission is still actively managing to UFE. JWST is also tracking milestones; none are late since the September 2011 re-planning activity. An Observatory Verification Matrix metric has also been developed. The mass estimate past CDR is at 76% and is being tracked, and charting of risk retirement performance is being done. The mission continues to execute to launch readiness date (LRD) commitments, with challenges ahead as the mission enters the critical integration and testing (I&T) phases. Dr. Yoder felt the right team was in place to carry through this activity and to successfully meet its commitments.

The Science Committee requested a clearer representation of JWST milestones regarding schedule and budget, so as to understand what went well and what went poorly, what has slipped, and how much cost is associated with such slips.

#### *Discussion*

Dr. Luhmann asked about the integration of JWST into Astrophysics activities as a whole. Mr. Yoder felt that overall the relationship with the community remains intact. Dr. Kathy Flanagan commented that an APD Program Scientist is overseeing JWST activities, and that the community has strongly embraced the science. There has been a successful workshop for which exposure time calculators were prepared, for example, indicating a strong interest even years before launch. Town hall meetings have been standing-room only.

#### November 15, 2012

##### Heliophysics Update

Ms. Victoria Elsbernd, acting Director of the Heliophysics Division (HPD), presented to the committee. HPD had a successful launch of its Radiation Belts and Storm Probe (RBSP) on August 30, 2012. The Atlas V performed flawlessly, and phase E activities started on 29 October. The mission's new name is the Van Allen probes, after the discoverer of the belts, marking the first dual spacecraft mission that will investigate these belts. BaRREL, to augment the Van Allen mission, will start on 1 January at the Antarctic; the mission has 25 payloads, 5 of which are spares, and there will be 5-8 balloons aloft at any given time, measuring electrons that drop from the belts into the atmosphere. Magnetospheric Multi-Scale (MMS) is on track, with launch scheduled for October 2014, and an external commitment date (ECD) of March 2015. The Space Environment Testbed (SET) mission is moving to mid-2015.

MMS completed KDP-D and completed its systems integration review (SIR) in August 2012. A Program Management Council (PMC) approved phase D in October 2012. MMS remains within cost commitment although resources are tight. It is a complex mission with 25 instruments on 4 spacecraft, and is making excellent progress in instrument integration. FY13/14 key milestones include Solar Orbiter's KDP-C in December. The IRIS mission has an official launch date no earlier than late February 2013, but is under review, with no technical issues. The Research Opportunities in Space and Earth Sciences (ROSES) NASA Research Announcement (NRA) will be released in February 2013, including technology studies.

The next HP Explorer announcement is anticipated in 2015. Explorer full-mission concepts are under review as well as 3 missions of opportunity (MoOs).

The Heliophysics Decadal Survey was received in August, and HPD is revisiting its roadmap process in response. NASA and ESA held a bilateral meeting in early October, and a Survey of Decadal Surveys (Lessons Learned) is under way; a report will be coming out in summer 2013. Accomplishments planned for HPD include BaRREL, IRIS, MMS, Solar Orbiter (SO) and Solar Probe Plus, as well as a Senior Review of operating missions in Spring 2013, and a review of the Survey of Surveys. Dr. Jeff Newmark, in response to a question, commented that HPD is still on track to have a brief-out on the roadmap process at the AGU; this will be an interim status report. HPD expects to finish its roadmap review by early 2013.

Dr. Maura Hagan, Chair of the Heliophysics Subcommittee (HPS), provided an update on subcommittee activities. She mentioned highlights of the new Decadal Survey and its science goals for the next decade: determining origins of the sun's activities, predicting variations, studying dynamics and coupling, studying the interaction of the sun with ionosphere/thermosphere/mesosphere (ITM), and fundamental processes.

Recommendations from the Decadal Survey are to complete the current program; implement the DRIVE initiative (diversify, realize, integrate, venture, educate); accelerate and expand the Explorer program; restructure the Solar Terrestrial Probes (STP) program as a moderate scale PI-led line; and to implement a large Living with a Star (LWS) mission to study the ITM system in an integrated fashion. LWS is a flagship class program, within which Solar Probe is now being planned. STP is not moderate-scale at present.

As to the future-enabling budget scenario, Dr. Hagan noted that the GDC, the next large mission of the LWS after Solar Probe, rises above the curve in order to achieve a more efficient spending profile, as well as to achieve deployment for the next solar maximum in 2024. The trend is to push out missions, with reallocations made as the program moves forward in time. HPS discussed the roadmap at length, the charter of which is to align HPD with the Decadal Survey, to create a program that can be sustained within resources, and to develop high-level mission studies. The roadmap committee is chaired by Ed DeLuca and is following an aggressive schedule; the committee hopes to have notional ideas solidified at the time of the December AGU Town Hall meeting.

Two specific HPS recommendations include a strong endorsement of the funding priorities described in the Decadal Survey, including the decision rules, that should be reiterated in the roadmap. HPS has asked to be updated on a regular basis. HPS put forth 7 recommendations for HPD to consider for the upcoming Senior Review, regarding obtaining data, optimizing calibration/validation measurements, and archiving data; making the data available from the broadest number of sources; separately evaluating the proposed science; considering what community science could be done with the available data; looking at individual instruments vs. missions as whole; assessing technical management and total cost evaluations with respect to the value of data; and encouraging a healthy Guest Investigator program.

HPS has tried to understand cost growth within the Division and received some encouraging presentations in response. In terms of launch vehicles, HPS heard a presentation from the Launch Services Program (LSP) and found that the LSP is providing excellent service. HPS put forth a draft recommendation that NASA should formally review the existing national cyberinfrastructure, a comparison with best of breed practices within NASA and other Federal agencies. HPS believes that NASA should conduct a self-study, while stating that an emphasis is on data is important. Dr. Huntress felt it important that the Science Committee should respond to this recommendation, as it is important that SMD get ahead of it to make

sure that NASA science requirements be considered. All SMD divisions should hear from Larry Smarr. Dr. Feeley noted that he was working to get all the subcommittees briefed. Dr. Luhmann added that there are also local data systems, and Virtual Observatories to consider. Such a review must be careful to get to the user experience. Dr. Huntress agreed, adding that data systems in science are ahead of the rest of the Agency. Dr. Tapley remarked that the issue is broader than data systems, as it impacts computational modeling. Dr. McComas agreed that Dr. Smarr has a very strong committee of leading IT experts (Google, e.g.), and that this is a great opportunity to team with them in order to get science needs met. Dr. Hagan noted that one should avoid breaking anything in attempts to improve the infrastructure.

Dr. Hagan presented science highlights from Solar and Heliophysics Observatory (SOHO)/Solar Dynamic Observatory (SDO) observations, pointing to origins of the 11-year sunspot cycles. Based on extreme ultraviolet (EUV) measurements, the evolution of these bright EUV spots appears to be related to the sunspot number. These results hint at links to deep origins of solar cycle and underlying signatures of a 22-year cycle. The RBSP/Van Allen probe has already revealed some science results during its commissioning phase: a high electron count in the outer belts and a high-proton population inner belt, and providing a 3D view of the inner and outer belts. The probe has also recorded sounds associated with the belts- a “chorus” that sounds much like the dawn chorus of birds. Radio receivers have historically picked up this chorus, more easily in the morning. During the recent extended solar minimum, evidence of tropospheric influence on the near-space environment has also been found, with implications for ion-neutral coupling and electrodynamic effects. These are zonal wind wave 4 patterns that vary with longitude. In response to a question, Dr. Hagan reported that the DISCOVER is still in the offing, but the Decadal Survey has recommended that the Interstellar Mapping and Acceleration Probe (IMAP) go first because it has an L1 monitor on it. Dr. McComas added that the science of IMAP is designed to take a step beyond the Interstellar Boundary Explorer (IBEX), increase resolution, by dwelling in a halo orbit around L1, replacing the capabilities of ACE and building in sensors to measure the solar wind in near-real time. Committee members agree that the lack of presence of a coronagraph on DISCOVER remains an issue of concern. The Science Committee reviewed the HPS finding on a cyberinfrastructure study. Dr. Huntress held the issue until the rest of the Divisions were heard. Dr. Hagan recommended that the remaining science subcommittees hear a briefing from LSP.

#### Astrophysics Update

Dr. Paul Hertz, Director of the Astrophysics Division (APD) presented a status of the division. Science highlights included the first evidence of a planet destroyed by its star, indicated by an excess of lithium in its spectrum, implying recent destruction of a planet by a red giant; there is a remaining planet in a highly elliptical orbit, also implying recent change. Cosmic fog as seen by the Fermi spacecraft, in the form of scattered gamma rays, have enabled a calculation of the stellar density. These data show that the average distance between stars in the universe is 4150 light years. A Chandra image of a galaxy, nicknamed the Phoenix cluster, has shown the largest amount of new star formation ever seen. Compression of gases is triggering off a new round of star formation in this particular galactic center, as the supermassive black hole is “turned off,” allowing more gas to flow into the center. Hubble/Spitzer results have yielded the image of a galaxy aged approximately 500 M years post-Big Bang.

Dr. Hertz reported on the current Astrophysics program. NuStar is the Division’s most recently launched mission, which began phase E in August. Problems with the alignment of star tracker heads have been resolved, as well as calibration issues, and science observations are now going well. NuStar has generated an x-ray image of the Milky Way’s galactic center, viewing a flare that probably represents an asteroid-sized ingestion. The Stratospheric Observatory for Infrared Astronomy (SOFIA), grounded since December 2011 for planned completion of observatory systems, has selected science for Cycle 1 investigations, is undergoing avionics refurbishment, and is having a new fine guidance camera installed. By the beginning of December SOFIA will begin Guest Observer observations for about a year.

The AstroH mission is in development for launch in 2014, has experienced some I&T progress and is manufacturing the flight unit. NASA will be providing the calorimeter and mirrors for this mission and the Japanese Space Agency JAXA will be providing a dewar. A heat switch had a failure, which had an impact on the I&T testing. The impact on the schedule is to be determined. Cryogenic testing of the engineering model has resumed and the instrumentation currently has better spectral resolution than required. Euclid, an ESA mission, is going forward, with NASA providing sensor chip systems for the Near Infrared SPectrometer and Photometer (NISIP) instrument. NASA will procure detectors from Teledyne and characterize them inhouse; and a memorandum of understanding (MOU) will be signed after it is approved at ESA's next council meeting.

A termination letter was sent to GSFC in September 2012 to terminate the GEMS mission, which will be closed out by the end of the year. APD has received a Lessons Learned report from the center. Two important lessons were the importance of the clarity of communication, and to think carefully of what is meant by a Small Explorer (SMEX). These missions were originally conceived as an opportunity for less experienced people to gain experience. Currently, however, SMEXes are cost-capped, with no room to make mistakes. It is no longer a place to allow the inexperienced to make mistakes; at the very least a SMEX requires an experienced Project Manager. The suborbital program should now be considered the niche for inexperienced investigators. The PI must have the right kind of mentoring.

Asked if there were any way to return SMEX to its original state, Dr. Hertz reported discussions with the Office of Safety and Mission Assurance (OSMA) and OCT. He added that the 2007 Announcement of Opportunity (AO) had many ways to give this relief, however, waivers were not approved. This AO was an experiment that was not successful. NPR 7120.5 lays out the rules for development, but also allows tailoring through waivers. The environment evolved in such a way as to hamper the execution of the guidelines. Dr. Luhmann mentioned that an NRC study on PI-led missions found the same issues, that rules change after selection. Dr. Huntress noted that waivers need to be negotiated before an AO is issued. Dr. Tapley commented that the only currency a mission has is science content. It is an issue for the whole range of PI missions. Dr. Huntress worried that the Agency tends to default to the most conservative approach.

APD is taking advantage of the International Space Station as a useful platform for particle astrophysics with the placement of DOE's Alpha Magnetic Spectrometer (AMS) aboard. CALET on the JEM exposed facility is scheduled for 2014; JEM-EUSO launch is planned for 2017; and ISS-CREAM, a re-packaged balloon instrument, is planned for 2014. Flying the CREAM balloon experiment on ISS is about 50% more costly, but the science return is expected to be an order of magnitude higher. Within the Explorer program, funding that would have spent on GEM is now available with the Explorer Program for moving out aggressively, and APD will move up dates for future AOs. A full mission and mission of opportunity (MoO) is to be selected in Spring 2013. An AO for a MoO is currently on the street with selection in Summer 2013. In a year or so, APD will have a SMEX AO, and an AO for a full Explorer and MoO in 2015.

The recently proffered National Reconnaissance Organization (NRO) telescopic assets have been reviewed, and the Administrator has directed that two studies be performed. A quick Design Reference Mission is being done for the science of WFIRST, and a seven-month study is under way to assess the use of the 2.4 m-telescope; the mirrors are not cryogenically cooled, and some WFIRST science requires infrared imaging. The telescope will provide more photons, but less spectral breadth into the infrared. APD is also considering a notional secondary instrument (currently using a coronagraph as a stand-in). A broad study also being done by SMD to identify other uses of the telescope assets to advance any NASA objectives. The hardware has been declassified, and technical information is in process of being

declassified. Looking at Earth is the only task off-limits to this telescope.

Dr. Hertz reviewed the APD implementation plan. The Astrophysics Decadal Survey was released in 2010, and the budget environment has changed since then. APD is creating a white paper to communicate with the community as to how APD will carry out the DS. The strategy is to move forward with missions responsive to the Survey within NASA resources. APD cannot currently begin implementing any large missions, and must delay new starts until funding becomes available as JWST approaches launch. The Division is therefore studying medium-class missions that flow from science priorities of the Decadal Survey prioritized activities. These missions are called probes (under about \$1B). The budget does not support starting a new large mission before 2017. APD is responding to each prioritized recommendation in the Survey, preparing for the next strategic mission while studying both WFIRST and probes. The near-term strategy is to complete mission studies, make decisions in mid-decade, and also request a mid-decade review by the NRC to revisit the program. The white paper will be released to the community by mid-December 2012.

Dr. Peterson presented results from the APS. The APS met by telecom last week and confirmed that the Division will stay true to New Worlds/New Horizons science priorities; specific processes can't be well-defined at this time and the APS will report back to the Science Committee after the implementation plan/white paper has been distributed. APS has also recommended that NASA conduct the review of NASA's cyber infrastructure led by the NAC's Information Technology and Innovation Committee. SMD archives such as HEASARC, MAST, and IRSA, which grew out of missions in particular wavelength regimes, have proved to be a highly effective regimen for Astrophysics. There are concerns, however about increases in astronomical data in the archives and the increasing demand for data. NASA has already developed a multiagency Virtual Astronomical Observatory (VAO), and data centers are scrutinized as part of the NASA Senior Review process every 3 years. APS feels that NASA data centers are committed to high-capacity and low-cost operations, and embedding the data archives in APD ensures that scientists maintain this efficiency. A 2007 NRC report reached similar conclusions, finding for instance that Guest Observatory facilities can be easily moved into existing centers. Therefore APS believes current Astrophysics data archives already constitute a best practice, and must remain science-driven.

Dr. Luhmann suggested that APS brief other subcommittees on the cyberinfrastructure issue. Dr. Hertz offered that a Director of any of the three archives could do this. Dr. Hagan commented that by contrast to Astrophysics, Heliophysics does not have a centralized system, raising concerns about the ability to search archives. Dr. Hertz added that APD uses interoperability protocols (developed for the VAO) that allow queries of many databases from more than one archive. Dr. Hagan raised another Heliophysics concern in terms of bandwidth; new missions have been providing enormous images of sun. Dr. Hertz noted that in some cases, analysis can be done locally with the data, or supercomputing needs can be performed at dedicated centers. Dr. McComas felt that as a study is going to be done in any case, scientists should help inform it as much as possible. The Science Committee generally supported an active role for SMD in the impending study.

#### Earth Science Division Update

Dr. Michael Freilich, Director of the Earth Science Division (ESD), presented a status. Five major missions will be launched over the next two years, within recommendations issued by the 2007 Decadal Survey. ESD operating missions include 16 orbital missions, which will undergo a Senior Review in early 2013, yielding have multiple recommendations by June 2013. Recent science highlights include space observations of CO<sub>2</sub> in megacity areas taken by GOSAT (JAXA); NASA science teams were invited to help reduce this data and were able to apply Orbiting Carbon Observatory (OCO) algorithms to the data set. Urban areas were estimated to contribute 70% of CO<sub>2</sub> emissions to the atmosphere. TRMM



observations of Hurricane Sandy yielded detailed images of a tropical cyclone evolving into a mid-latitude storm. Maximum precipitation measurements over the ocean were found to be 26 cm.

Venture-class missions, as recommended by the Decadal Survey, continue to be fully funded, with 3 “strands:” Earth Venture (EV), a competitive, PI-led, science-driven and cost/schedule-restrained strand; a suborbital, smallsat strand; and an instrument strand. Venture-class missions are designed to be solicited on a regular basis, with studies designed to complement the systematic missions identified in the Decadal Survey. Five EV investigations have been selected for the suborbital strand, and flights began in FY11. The first smallsat has been selected, the Cyclone Global Navigation Satellite System (CYGNSS), which is scheduled for July 2012, and an instrument, Tropospheric Emissions: Monitoring of Pollution (TEMPO), was selected in November 2012. So far solicitations have been on schedule. Four of the five EV Airborne missions will have completed a field campaign by early 2013. A second suborbital solicitation is funded in preparation for release in mid-2013. The EV-2 smallsat is using “Class D” management approaches and processes; to keep it at this level, the approach is to meet with the Program Office and review the matrix of requirements, line by line, working closely with the PI. It is incumbent on the PI to demonstrate why the approach works. Dr. Huntress suggested that the Office of the Chief Engineer (OCE) be aware of the recent Small Explorers (GEMS) problem when carrying out this approach. Dr. Freilich agreed, adding that ESD is attempting to document this approach as well.

The TEMPO instrument will fly in a geostationary orbit; retrieve ozone, NO<sub>x</sub>, SO<sub>x</sub>, aerosols, CH<sub>2</sub>O and other species. Its measurements will be simultaneous with the European GEMS Sentinel 4 and Korean GEO AQ missions, fitting into a global observation scheme. ESD is carefully documenting to establish processes for future efforts.

The ESD budget strategy remains the same: a balanced program focused on Earth systems science, operating with interagency and international partners, and playing an increasingly leading role in developing international coordination bodies. The FY12 and FY13 budget requests are essentially the same. The flight portfolio for the next decade includes the LandSat Data Continuity Mission (LDCM), Global Precipitation Measurement (GPM), Strategic Aerosol and Gas Experiment (SAGE)-III, Soil-Moisture Active-Passive (SMAP) and OCO-2 (July 2014). The portfolio represents a substantial reinvigoration and expansion of the Earth-observing satellite constellation. ICESat-2 will be going to confirmation review within the next 2 weeks, GRACE-FO in 2017, and OCO-3 is likely to fly on ISS in Fall 2017. Surface Water and Ocean Topography (SWOT) and Pre-Aerosol, Clouds and Ocean Ecosystem (PACE) are progressing. Launch vehicles have been identified for virtually all the Decadal missions. The Gravity Recovery and Climate Experiment (GRACE)-FO will fly on a German-provided launch vehicle, and the CYGNSS smallsat was designed for a Pegasus-class vehicle; this latter mission is being discussed with LSP; ESD is willing to accept a first flight for this mission.

The ESD Airborne program is developing a variety of missions; some are pathfinders and some are critical. The program enjoyed a good summer for the first flight of instrument investments and is using quite a few aircraft to demonstrate/deploy them, such as Sherpas, DC-8s, Lear jets, etc. Findings from the mid-decadal assessment indicate ESD has fulfilled recommendations in this area; the assessment also found a healthy investment in R&A. Earth observations from ISS continue, including the HICO hyperspectral coastal ocean imager, and ISERV, a digital camera and telescope. Other planned instruments funded by NASA/HEOMD, with ESD funding for analysis, are a lidar experiment (summer 2013), Rapid-Scat, Lightning Imaging Sensor (under consideration), and a hyperspectral follow-on to HICO (under consideration). These are generally Class D-minus in cost. Approved instruments funded by ESD include SAGE III and OCO-3 (\$100M range). Issues of concern for ESD are launch vehicle cost and availability; capabilities of the airborne program, especially unmanned aerial vehicles (UAVs). For a sustained set of campaigns, ESD must work to maintain infrastructure in the face of potentially significant

external budget perturbations. To fly UAVs, ESD works closely with the Federal Aviation Administration (FAA) closely, and ESD also supports a detailee at FAA. All planned UAV work is done over the ocean to avoid corridors. ESD has also run a solicitation with the Aeronautics Research Mission Directorate (ARMD) for a series of missions to demonstrate the ability to fly UAV and manned vehicles simultaneously.

Dr. Tapley presented findings and recommendations from the most recent Earth Science Subcommittee meeting. There are no findings at present; ESS will formally meet again at the end of November. ESS has held 2 telecons in the interim period, concerning an ongoing Joint Program Satellite System (JPSS) status activity, and launch vehicles. Other topics from the March 2012 meeting include a review of the extensive ground network, modeling programs, Earth Science communications, and applications and satellite mission implementation. The Suomi NPP mission launched in October 2011; ESS recognizes that NOAA requirements differ from NASA's requirements for this mission, therefore NASA will need careful calibration/validation in comparison to NOAA. Thus far the Visible Infrared Imager Radiometer Suite (VIIRS) instrument has been able to capture ocean color well, and can give measurements of chlorophyll. The ozone mapping profiler images the ozone hole well, which points up the importance of calibrations. Flying VIIRS and the Ozone Mapping Profiler Suite (OMPS) together will provide global composite data on dust and aerosols. JPSS issues remain, as budget issues threaten a number of instruments on JPSS1/2; processing algorithms for sensor data are not clear, and calibration/validation issues remain. It is not clear what higher-level products will be developed through NOAA.

Other ESS issues include the evolution of the suite of assets on orbit. Mission cost growth is a continuing concern, especially in the area of launch vehicles, science requirements, continuity of measurements, the role of interagency/international collaboration, the GEOSS/CEOS role in satisfying observation requirements, and modeling and data system modernization. The Focus of the next ESS meeting will be the assessment of NRC midterm report, cloud computing and data distribution, a JPSS data product specification assessment of program balance and execution, and any issues emanating from the program status update.

#### Public comment period

No public comments were noted.

#### *Discussion*

Administrator Bolden joined the Science Committee for a brief discussion, and commented on the experience of the Curiosity landing, observing that the preparation and management of public expectation was impressive. Mr. Bolden reminded the committee of NASA's obligation to keep succeeding; the Agency must be persistent, and tell the science story at every moment. Mr. Bolden stated strongly that NASA does not intend to rob science for human exploration, or vice versa, nor does the Agency intend to merge budgets or directorates. He stressed that NASA can't set foot on Mars without science; HEOMD recognizes this too. There is much pull and tug in the Agency over these issues. Hypersonic research must go on as well, as it is integral to exploration. Mr. Bolden encouraged committee members to work proactively with the Administration and Congress in furthering the science agenda.

#### Meeting with SMD Associate Administrator

Dr. John Grunsfeld, Associate Administrator of SMD, met with the committee, and thanked members for their service. In response to a question, he revealed no plans for how SMD would react to a possible sequestration in January 2013, although he felt that it should be clear to everyone that SMD is not looking to adversely affect the preferred programs from the various Decadal Surveys. SMD is still planning to a flat budget without inflation in the out years. Opportunities will be fewer and far between, with an emphasis on meeting current obligations, and maintaining and building credibility, to overcome

skepticism from outside stakeholders, such as the Government Accountability Office (GAO). Dr. Grunsfeld noted the recent success of Curiosity's landing on Mars, and its ability to capture the attention of some 50 million people. NASA must work more to engage the public, as doing science is not a public entitlement. Researchers must be appreciative of this issue in constrained budget times. SMD can make adjustments to balance the science program within the overall budget levels, which are not foreseen to change. Scientists will have to play a role in making sure NASA has maximum public engagement in science.

Addressing an overarching vision for SMD, Dr. Grunsfeld expressed interest in how each Decadal Survey can serve in setting up the decade that follows. To this end, he had asked that NRC emphasize science priorities when developing surveys, and he displayed an exercise in graphics to illustrate the future of ultraviolet/visible/infrared Astrophysics as a messaging tool, in an effort to show the connection between the elements of the program in a spatial and temporal configuration. Exoplanets, for example, can be made very compelling. Could ISS be used to build a small telescope purely robotically, such that one could launch pieces of a very large telescope that could ultimately be built in space? In 2030, can we build a 20-meter telescope for \$8B?

For Mars, the next step is sample return, followed by future Mars exploration by humans. SMD is using the Mars Exploration Rover (MER) as a metric (\$1B), to compare it to what a human could do. It is estimated that a human on Mars could deliver a 100-fold greater science return than a rover. Can \$200B get a human to Mars? The science return is about the same per unit time. SMD will have to plan to science returns that are beyond human lifespan horizons. He cited the most recent Heliophysics Decadal Survey as a worthy effort, which could be used as a good template for the future.

#### *Discussion*

Committee members asked general questions of Dr. Grunsfeld. Dr. Luhmann commented that the public seems to have a misperception of NASA cost and that the Agency still has an image problem. She appreciated the idea that scientists are not entitled to funding, but offered that they do feel ownership of the science program. There are anxieties in the planetary community outside of Mars, as the community wants to retain its best experts. Dr. Grunsfeld felt that OMB was trying to support science at NASA. In turn, scientists must have a meaningful dialogue with Congress on matters that support science and take a long-term view. He emphasized that NASA will be leveraging international missions as well. After the next budget review, the Agency will have a better idea of what the next U.S.-led planetary mission will be.

Dr. Hagan appreciated Dr. Grunsfeld's acknowledgement of the Heliophysics Decadal Survey, and asked about the future of HPD management. Dr. Grunsfeld responded that he had written the position description for the Division Director slot, which will be posted on USA Jobs shortly. He stressed that this Senior Executive Service (SES) position is a very serious responsibility, and recommended reading Len Fisk's recent presentation at NRC regarding NASA staffing.

#### Findings and recommendations

The committee deliberated on findings and recommendations. Dr. Huntress called for Dr. Larry Smarr to brief the committee on the impending cyberinfrastructure study, having reached a consensus that SMD would like to take an active role in supporting the study. He further suggested using elements of the Maizel presentation to express concern about workforce numbers to the NAC, and to offer anecdotes from his own experience. Cycles of downsizing have been seen before, and it would be wise to consider the resultant pressure on the workforce. He agreed to bring the PPS recommendation back to the NAC and is awaiting Dr. Levy's white paper that provides a more detailed justification and rationale to support this recommendation.

It was the sentiment of the committee that discipline subcommittees should decide the issue of program balance independently and communicate it to their respective division director. There was a brief discussion of how continuity is related to both funding and program balance. Dr. Hagan stated for the record, that a finding on launch services is premature, as other subcommittees should first hear the LSP briefing, and the SMD briefing on mission cost growth, before making a final assessment. Dr. Huntress requested that LSP brief to the full committee. Dr. Feeley agreed to schedule the requested briefings. Dr. Luhmann suggested a briefing as well on the Survey of Decadal Surveys. Dr. Huntress adjourned the meeting at approximately 2:45pm.

## Appendix A Attendees

### NAC Science Committee members

Wesley Huntress, Carnegie Institute, *Chair Science Committee*  
Byron Tapley, University of Texas, *Vice Chair* and Chair Earth Science Subcommittee  
Maura Hagan, National Center for Atmospheric Research, Boulder  
Eugene Levy, Rice University, Chair Planetary Protection Subcommittee  
Janet Luhmann, University of California, Berkeley  
David McComas, Southwest Research Institute  
William McKinnon, Washington University  
Robert McPherron, Acting Chair Heliophysics Subcommittee  
Bradley Peterson, Ohio State University, Chair Astrophysics Subcommittee  
T. Jens Feeley, NASA Headquarters, *Executive Secretary*

† = *ex officio* member

### NASA Attendees

Waleed Abdalati, NASA Headquarters  
Marc Allen, NASA Headquarters  
Shannon Bartell, NASA Advisory Council's Human Exploration and Operations Committee (HEOC)  
Ralph Beaty, NASA Headquarters  
Max Bernstein, NASA Headquarters  
Charles Bolden, ***NASA Administrator***  
Joan Centrella, NASA Headquarters  
Leroy Chiao, HEOC  
Stephen Cole, NASA Headquarters  
Chris Collins, NASA Headquarters  
Joe Cuzzupoli, HEOC  
Victoria Elsbernd, NASA Headquarters  
Chris Flaherty, NASA Headquarters  
Michael Freilich, NASA Headquarters  
Michael Garcia, NASA Headquarters  
Chuck Gay, NASA Headquarters  
Jim Garvin, NASA Headquarters  
Barry Geldzahler, NASA Headquarters  
James Green, NASA Headquarters  
John Grunsfeld, NASA Headquarters  
J.D. Harrington, NASA Headquarters  
Ilana Harrus, NASA Headquarters  
Hashima Hasan, NASA Headquarters  
Jeffrey Hayes, NASA Headquarters  
Paul Hertz, NASA Headquarters  
Jeffery Hollingsworth, NASA Headquarters  
Tom Holloway, HEOC  
Jack Kaye, NASA Headquarters

Dick Kohrs, HEOC  
Dave Lavery, NASA Headquarters  
Robert Leamon, NASA Headquarters  
Tim Lee, NASA ARC  
James Lochner, NASA Headquarters  
Margaret Luce, NASA Headquarters  
Marian Norris, NASA Headquarters  
Martha Maiden, NASA Headquarters  
Roy Maizel, NASA Headquarters  
Richard Malow, HEOC  
Douglas McCuiston, NASA Headquarters  
Michael Meyer, NASA Headquarters  
Michael New, NASA Headquarters  
Jeff Newmark, NASA Headquarters  
Jim Odom, HEOC  
Jonathan Rall, NASA Headquarters  
Andrea Razzaghi, NASA Headquarters  
Diane Rausch, NASA Headquarters  
Shawanda Robinson, NASA Headquarters  
Wilt Sanders, NASA Headquarters  
Mitch Schulte, NASA Headquarters  
Bob Sieck, HEOC  
Eric Smith, NASA Headquarters  
Heather Smith, NASA Headquarters  
Ray Taylor, NASA Headquarters  
Craig Tupper, NASA Headquarters  
Shannon Valley, NASA Headquarters  
Gregg Vane, NASA JPL  
Glenn Wahlgren, NASA Headquarters  
Michael Wargo, NASA Headquarters  
Nicholas White, NASA Headquarters  
Dan Woods, NASA Headquarters  
Geoffrey Yoder, NASA Headquarters

Non-NASA Attendees

Linda Billings, George Washington University  
Anne Connor, House Science Committee  
Dom Conte, Orbital Sciences Corporation  
Tammy Dickinson, Office of Science and Technology Policy  
Joseph Dyer, Chair Aerospace Safety Advisory Panel  
Mary Engola, Ball Aerospace  
Kathryn Flanagan, Space Telescope Science Institute  
Bethany Jons, American Astronomical Society  
Brad Keelor, British Embassy  
Bill Mackey, Canadian Space Agency (Washington, DC)  
Jon Malay, Lockheed Martin  
Stephen Squyres, Cornell University, *Chair NAC*  
Joan Zimmermann, Zantech IT

Appendix B  
NAC Science Committee Membership

Dr. Wesley T. Huntress, Jr.  
Carnegie Institution of Washington (Chair)

Dr. Byron Tapley  
University of Texas (Vice Chair)

Dr. Maura Hagan  
National Center for Atmospheric Research

Dr. Noel W. Hinners  
Lockheed-Martin (retired)

Dr. Eugenia Kalnay  
University of Maryland

Dr. Charles F. Kennel  
University of California, San Diego (*ex officio member*)

Dr. Eugene H. Levy  
Rice University

Dr. Janet Luhmann  
University of California, Berkeley

Dr. David McComas  
Southwest Research Institute

Dr. Bradley Peterson  
Ohio State University

Dr. Meg Urry  
Yale University

Dr. T. Jens Feeley  
Executive Secretary  
NASA Headquarters

## Appendix C Presentations

1. Mars Science Laboratory Curiosity Status and Update; *Michael Meyer*
2. Planetary Science Update; *James Green and Janet Luhmann*
3. SMD Civil Service Workforce History; *Roy Maizel*
4. Mars Program Planning Group, Final Report; *James Garvin*
5. Planetary Protection Subcommittee Status; *Eugene Levy*
6. James Webb Space Telescope Status; *Geoffrey Yoder*
7. Heliophysics Update; *Victoria Elsbernd and Maura Hagan*
8. Astrophysics Update; *Paul Hertz and Bradley Peterson*
9. Earth Sciences Update; *Michael Freilich and Byron Tapley*



Appendix D  
Agenda

NAC Science Committee  
November 14-15, 2012

Wednesday, November 14 (MIC-3/Room 3H46)

8:30-8:40am            Opening Remarks – J. Feeley / W. Huntress

8:40-9:40am            Curiosity Status & Update – M. Meyer

9:40-10:40am          Planetary Science – J. Luhmann / J. Green

**10:40-11:00am            Break**

11:00-11:45pm          SMD Workforce – R. Maizel

**11:45-1:00pm            Lunch on Own**

1:00-2:30pm            Final Report of Mars Program Planning Group – J. Garvin  
– Joint meeting with Human Exploration & Operations Committee

2:30-3:00pm            Discussion

**3:00-3:15pm            Break**

3:15-4:00pm            Planetary Protection / PPS – G. Levy /C. Conley

4:00-5:00pm            JWST Status – G. Yoder

5:00-5:15pm            First Day Wrap-up – W. Huntress / J. Feeley

**5:15pm                    Adjourn for the day**

NAC Science Committee

November 14-15, 2012

Agenda  
(all times EASTERN)

Thursday, November 15 (Room 9H40)

8:30-8:40am            Opening Remarks/Announcements – J. Feeley / W. Huntress

8:40-9:40am            Heliophysics – M. Hagan / B. Giles

**9:40-10:00am            Break**

10:00-11:00pm        Astrophysics – B. Peterson / P. Hertz

11:00-12:00pm        Earth Science – B. Tapley / M. Freilich

**12:00-1:00pm            Lunch on Own**

1:00-1:10pm            Public Comment

1:10-2:00pm            Discussion with Associate Administrator

2:00-4:00 pm            Discussion, Findings and Recommendations

**4:00pm                    Adjourn**