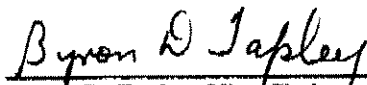


NASA ADVISORY COUNCIL
SCIENCE COMMITTEE

September 28, 2010

NASA Headquarters
Washington, D.C.

MEETING MINUTES


Byron D. Tapley, Vice Chair


T. Jens Feeley, Executive Secretary

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Remarks and Announcements

Dr. Byron Tapley, Vice Chair of the NASA Advisory Council (NAC) Science Committee, presided over the meeting.

Dr. T. Jens Feeley, Executive Secretary of the NAC Science Committee, opened the meeting, a one-day teleconference and Webex presentation. He made some brief logistical announcements, reminding members that the meeting was being held under full Federal Advisory Committee Act (FACA) guidelines, and that the notification concerning annual renewal of financial disclosure filing was approaching.

Open Access for SMD-Funded Research

Dr. Max Bernstein presented a briefing on a Science Mission Directorate (SMD) proposal to conduct an open-access pilot program for NASA-funded research papers, referring to the fact that some publications resulting from NASA research are openly available, and some are not. SMD thinking is that all NASA-funded research should be openly available to the community. While there is Congressional language pending that will eventually require open access to such documents, SMD in the meantime would like to begin a pilot activity in open access.

Current practices in fee-for-service vary. *Astrophysics Journal* authors pay a charge upfront for publications. *Icarus*, a Planetary Science journal, charges no fees for authors; readers instead must pay for manuscript access. Funds that authors pay in advance to such journals typically come out of the proposal for the Principal Investigator (PI) in the case of *Astrophysics*. It appears that the community most greatly affected by the change in practice would be the Planetary Science community. Rather than changing policy, SMD would like to do a pilot study in open access to explore the potential impact of the change. SMD thus plans to instruct centers to publish open access papers, supported by funds from the Office of the Chief Scientist, in order to obtain an estimate of where publishing is taking place, and to get sense of the viability of the open-access practice. The study is planned for FY11 (once the Federal budget is passed), and will apply only to civil servant-published papers from NASA centers. The pilot study will be revisited after one year. Dr. Michael Turner commented that using a pilot study would be a sensible way to proceed, to avoid unintended consequences; one would not want to put the government into competition with the journals. A pilot is a more gentle approach. Dr. Bernstein responded open access is generally thought to be beneficial for research, while others have contested this notion. No objections were noted from Science Committee members. Dr. Feeley noted that he would inform the SMD Associate Administrator, Dr. Edward Weiler, of the committee's approval.

Earth Science Division (ESD) Update

Dr. Michael Freilich, Director of ESD, presented an update of division activities. Operating missions are continuing to measure many different variables to advance the science of the integrated Earth system and provide benefit to society, using a comprehensive constellation of satellites. There are at present 13 fully operating spacecraft, with the recent loss of ICESAT-1 and QuikSCAT. With the augmented budget of FY09-10, ESD is planning to reinvigorate and expand the constellation, as well as to broaden research and technology development efforts. There are 16 major launches planned for the next decade, including major foundational missions. Since July 2010, the flight mission story has been a mixed one, however. The ICESAT-1 satellite re-entered Earth's atmosphere on 30 August; ESD had delayed the passivation of this mission after the science community had proposed a way to obtain unique GPS measurements as the satellite de-orbited. NASA responded favorably to the proposal and as a result collected some serendipitous science data. The Glory (aerosol distribution and atmospheric scattering) mission, originally scheduled for a November/December 2010 launch, has been moved to February 2011 due to instrument and launch vehicle challenges, as well as to reduced availability of the payload processing facility. The

Aquarius (sea surface salinity) mission has been delayed to April 2011. This collaborative mission with Brazil's space agency, CONAE, continues to deal with issues: the U.S.-supplied thrusters are contaminated and in the process of being replaced, and CONAE productivity has been disappointing, thus there is a risk of further delay. The NPOESS Preparatory Project (NPP) planned for October 2011 is also in some jeopardy. On the favorable side, a Critical Design Review has been held for the Orbiting Carbon Observatory (OCO-2) mission. OCO-2 is proceeding well toward its 2013 launch date on Taurus XL. If the Taurus vehicle performs well during the Glory launch, OCO-2 will be more assured of success. Soil Moisture Active-Passive (SMAP); ICESAT-2; Deformation, Ecosystem Structure and Dynamics of Ice (DESDynI); and Climate Absolute Radiance and Refractivity Observatory (CLARREO) missions are proceeding well, but must stay within program restraints to succeed. DESDynI's final baseline design will be reviewed by the Earth Science Subcommittee (ESS) in November 2010 to ensure it remains a science-driven mission.

In integrating missions and activities, Dr. Freilich noted progress in ESD missions that address key societal challenges, with significant advances being made in understanding the global state of fresh water availability and quality. The Tropical Rainfall Measuring Mission (TRMM) is planning an extended mission (EM) with Japan. In addition, ongoing field campaigns are providing new information on hurricane and storm formation. Data on inland waters will be provided by the 2019 Surface Water Ocean Topography (SWOT) mission. The Gravity Recovery and Climate Experiment (GRACE) mission continues to provide global mass flux measurements, including quantitative measurements of subsurface water changes relating to the depletion of aquifers. A GRACE follow-on mission is being planned for 2016. Data on glacier and ice sheet changes will be provided by the ICEBRIDGE, ICESAT 2 and DESDynI missions; coastal water quality will be measured by the planned PACE mission in 2019-20. A unique focus on northern latitude lakes, land, permafrost will be accessed via a number of future missions, including SMAP and SWOT.

Sustained global measurements made by OCO-2 and OCO-3, and Active Sensing of CO₂ Emissions Over Nights, Days, and Seasons (ASCENDS) missions in the next decade will contribute to integrated carbon cycle research and monitoring. Measurements of terrestrial aboveground mass will be made by the EV-1 AirMOSS, ICESAT-2, and DESDynI missions. Measurements of carbon in the ocean will be provided by the proposed Visible and Infrared Imager/Radiometer Suite (VIIRS) instrument on NPP, as well as through PACE and a variety of research programs. ESD maintains a structured program to take advantage of the integrated nature of the Earth-observing system.

International collaborations are under way between ESD and the European Space Agency (ESA). NASA officially signed off on an international framework with ESA in September 2010, with the purpose of coordinating instruments and planning for potential future flight missions. ESD is also making progress on interactions with India regarding development of a scatterometer and ocean color instrument, as well as data exchanges, and has reoriented its QuikSCAT mission to allow use of transfer standards. ESD and the French space agency CNES are finalizing the SWOT work package, as well as the provision of an instrument for PACE. ESD is also collaborating with the Japanese agency JAXA on TRMM, ASTER, and AMSR-E extended missions. Dr. Freilich noted however, that the Japanese are moving toward a more restrictive data policy. ESD also collaborates with Germany on the GRACE extended mission.

Interagency collaborations include an ongoing relationship with the United States Global Change Research Program (USGCRP). ESD recently presented to the Office of Management and Budget (OMB), a report detailing NASA contributions to USGCRP. While representatives from the Joint Polar Satellite System (JPSS, formerly NPOESS) and NASA's Joint Agency Satellite Division (JASD) are coordinating with SMD, significant issues remain with Department of Defense (DoD) contributions. The US Geological Survey (USGS) and the Department of Interior continue follow-on discussions with NASA on sustained Landsat measurements.

Dr. Freilich noted that two field experiments had been recently completed, demonstrating the breadth of ESD science, including results from the GRIP campaign just coming to a close. GRIP studied tropical storms and hurricanes to examine processes that lead to intensification and weakening. This was a very successful coordinated flight program of both manned and unmanned flight systems. Technical accomplishments were achieved in the use of the Global Hawk unmanned aerial vehicle (UAV), which demonstrated tremendous range, loitering for 15-20 hours over Atlantic storms after becoming airborne from a West Coast site. GRIP collected 20 separate transects of the eye of Hurricane Karl, to cite one example. ESD also finished the first NASA oceanographic study of the Chukchi Sea, which sampled optically complex waters and collected data about phytoplankton biomass, and also gathered data about the temporal and spatial availability of chlorophyll A, revealing high spatial variability in the sea ice field.

Asked to detail DoD issues with NPP, Dr. Freilich attributed the essential problem to objections to funding expressed by the defense appropriation committees. Dr. Noel Hinners asked Dr. Freilich to comment on how the large volume of Earth Science data is integrated into modeling activity, and thence to policy guidance. Dr. Freilich responded that in terms of the written climate plan, data integration is codified; about 10% of the total ESD budget is dedicated to data system; making data available is a key element of the program with an emphasis on enabling scientists to contribute to models. He offered a more detailed presentation on data and modeling at a future meeting. Dr. Turner was pleased at the extent of international collaborations, commenting that Earth Science seems to draw more global interest in data products, and asked if there is a more formal structure in which all interested countries can gather to cooperate on addressing global needs. Dr. Freilich reported that the Earth Science community has been working toward this model via the World Meteorological Association, in existence for 4 decades. He also reported participating in the Committee for Earth Observing Satellites, a satellite forum that meets several times per year, in an attempt to harmonize programs and data distribution processes, as well as to develop capabilities.

Heliophysics Division (HPD) Update

Dr. Richard Fisher presented an update on the Heliophysics Division (HPD), beginning with flight program status. The next strategic mission up is Radiation Belt Storms Probe (RBSP), which recently completed a re-plan, and is making good progress. A major instrument announcement was completed for Solar Probe Plus (SPP), which is now in phase A contract status, and will be meeting in October for a kickoff. SPP will have a highly constrained payload in a 6.8-year mission within 10 radii of the sun, and will work in conjunction with Solar Orbiter. Instrument selections include a solar wind and alpha electron investigation; a wide field imager; a fields experiment; an integrated science investigation of the Sun; and an investigation entitled Heliospheric Origins with Solar Probe Plus (observatory scientist).

HPD is collaborating with ESA's Flagship-class Solar Orbiter mission, proposing to provide a launcher and 4 instruments to the payload, representing a leveraged investment of 4:1. Selection is due in June 2011.

BARREL, a mission of opportunity (MoO), has been experiencing some power issues. BARREL will fly in conjunction with RBSP; its goal is to emplace a sensor network to study the bottom of the radiation belt. The BARREL sensor web will be established by launching a series of balloons in 2013/14 by a university-based group. The group had logged 2 successful flights and then encountered problems with solar panels (a thermal issue). A test campaign is now under way to flight-test modified solar panels. Within the Solar Terrestrial Probe (STP) line, the next mission to fly will be MMS, which will examine the physical process of solar/Earth reconnection. MMS had a CDR in August, and completed a 50% design review in September. Dr. Fisher noted that Tom Moore and Craig Pollock have joined the MMS team. In the Explorers program, THEMIS has been transitioned to the ARTEMIS mission, having completed a final burn to reach lunar orbit, in which the spacecraft will collect data on solar wind and

shocks, the lunar environment and lunar magnetotail. The two spacecraft will remain at the Earth-Moon L1 and L2 Lagrangian points for about a year.

The Interface Region Imaging Spectrograph (IRIS) mission had a conditional Confirmation Approval. Triana, now known as DSCOVR, has been transitioned into a MOU with NOAA, and may possibly include a coronagraph. HPD recently had a Senior Review of 15 operating missions to assess their individual scientific values and their contribution to the System Observatory. A graduate-level textbook has been published as result of the Heliophysics Summer School held over the past few years in Boulder, CO. A Consortium for Heliophysics Symposium was held at Ames Research Center in August; as well as an important workshop on advanced computational capabilities. NASA held an ESA bilateral meeting in early September and has also kicked off the commencement of the Heliophysics Decadal Survey. CINDI and TWINS will be having end-of-prime-mission reviews in late September.

The suborbital program has had success in solving problems with Black Brant rocket motors, having made modifications in motor thruster nozzles; since that time there have been 4 successful launches; the motors are considered to be back in operation. An issue with the Nikha motors has also been addressed. Dr. Fisher reviewed some science highlights, noting that SDO has been able to see connection cause-and-effect phenomena that had been theorized previously. The Interstellar Boundary Explorer (IBEX) mission is due to issue a press release of the most recent map on detection of neutral atoms. IBEX can also see Earth's magnetic field and may be able to make observations of magnetotail.

Dr. Roy Torbert, Chair of the Heliophysics Subcommittee (HPS), reported on its most recent meeting. Five members have left HPS membership in order to participate in the Heliophysics Decadal Survey, and will be replaced in the upcoming months. Dr. Torbert summarized the subcommittee's two most recent findings. The first finding urges NASA to strengthen its advanced computational capabilities in the discipline, recognizing that Heliophysics data is running ahead of modeling. The second finding underscores the plight of system science within HPD; in this context HPS expresses concern that continued minimum science funding is hindering total science return on the Great Observatory system, especially during a prolonged and unusually quiet solar minimum. HPS is therefore urging HPD to clarify to the community that larger proposals are indeed available for system science investigations. Dr. Fisher mentioned that he would be meeting with the new Office of the Chief Technologist (OCT) deputy to quickly respond to the first finding. Dr. Turner, noting that APS members did not resign for Decadal Survey duty, was also intrigued by the advanced computational capability finding and noted DOE's expertise and commitment to high-end computing. In response to these observations, Dr. Torbert agreed that collaboration with the Department of Energy would be key to advancing computational abilities. In reference to the conflicts arising from service on the Decadal Survey committees or panels, Dr. Torbert added that the NRC Space Studies Board had made a determination of conflict for HPS, but not for APS. Dr. Paul Hertz felt that this inconsistency should be addressed to Charles Kennel at the next meeting of the Science Committee; Dr. Feeley made a note of this request.

Dr. Hinners remarked that there seems to be a larger issue in data assimilation, modeling and output, and asked if the Science Committee should address the matter for multiple disciplines. The Science Committee agreed to pursue the need for advanced computational abilities as a broader subject for discussion, and to bring the issue to the NAC for further assessment if necessary.

Planetary Protection Subcommittee Update

Dr. Eugene Levy, Chair of the Planetary Protection Subcommittee (PPS), noted that the subcommittee had not met since the last meeting of the Science Committee, and that PPS had transmitted two recommendations at that time. He reiterated that the PPS function exists to discharge U.S. responsibilities codified under the international Outer Space Treaty, in force since 1967. Relevant obligations related to this treaty involve the protection of humans, the Earth's environment, and science. Dr. Levy emphasized

the science protection aspect of PPS, particularly as it contemplates a change in space exploration policy as the private sector plans to conduct missions in space, and perhaps on the Moon. PPS, as a result, has recommended transmission of this finding to the NAC, in order to protect sites of previous lunar sites and impacts, and to protect the retrieval of artifacts if possible. The question also remains of the fate of microbial matter, and biological spores in the lunar environment. PPS has recommended that NASA pursue appropriate external avenues to avoid contamination of these areas. In response to this recommendation, the NAC confined itself to an observation that the value of these objects was high, but did not recommend a specific NASA action in response. PPS will take up the question again, but Dr. Levy noted that the Office of Science and Technology Policy (OSTP) provides specific language implying that NASA possesses more authority than NAC believes; Dr. Levy therefore anticipates a broader response through the Science Committee to the NAC. PPS also issued a second finding on the supporting an independent reporting status of PPS, as there are inherent conflicts between PPS and science and exploration, which are not insidious but natural. However, the Science Committee declined to carry this reporting recommendation to the NAC.

Dr. Levy concluded that in addition to the usual PPS activities, there will also be an increasing need to bolster the resources of PPO to support R&D pertinent to Planetary Protection; the subcommittee plans to pursue this further with the Science Committee. Planetary Protection is challenging from many perspectives, even within the context of the robotic program within the Exploration Systems Mission Directorate. Human exploration will further complicate the issue for Planetary Protection, a circumstance that supports a rationale for increasing the resources for R&D.

Astrophysics Division Update (APD)

Dr. Jon Morse, Division Director of APD, and Dr. Alan Boss, APS Chair, gave an update on the Astrophysics Division (APD) and the Astrophysics Subcommittee (APS). Dr. Boss presented some science highlights, including recent results from Spitzer's SWIRE Survey, wherein galaxy clusters were viewed at very high redshift. Galaxies only 4 billion years old were seen to have active star formation, contrasting with (nearer and older) galaxies in the local neighborhood, indicating that star formation seems to start early on in galactic centers, and then moves to the edges of galaxies. Another image from WISE, targeting the Rosette Nebula, indicated the formation of many OB stars in this region. Data and press releases have been numerous this year, notably from the Kepler mission, which located the first multiplanetary system to be found by transit photometry. Two Saturn-sized planets were found in this system, with a hint of a third Earth-sized (1.4-1.5 times the radius of Earth) planet, a result which will need confirmation. If confirmed, the system would be the first 3-planet transiting system.

During the most recent APS meeting held September 16-17, subcommittee members discussed the release of the Astro2010 Decadal Survey, especially the top-level recommendations in the category of large space projects. The Survey's highest such priority is WFIRST (Wide-Field Infrared Survey Telescope), which will aim to achieve a large-scale galactic survey, perform microlensing exoplanet surveys, and undertake dark energy studies. The life-cycle cost of WFIRST was estimated in the Astro2010 report at \$1.6B (in FY2010 dollars), and thus the mission will not see any substantial investments until after the James Webb Space Telescope (JWST) launches. As a second-ranked priority, the Survey also called for re-invigorating the Explorer program, a result the community finds quite significant. Third and fourth priority projects are LISA and IXO, respectively, to be launched in the next decade. APD pledged to accept and implement the Survey, and the APS expressed its support of the intention in its findings. A brief discussion ensued about the cost definition of a Flagship mission, generally construed to be \$1B and above.

JWST is currently planned for a mid-2014 launch. Dr. Boss reported that a recent Testing Assessment Task group found that the JWST testing period can be shortened by 2-6 months, possibly helping to maintain schedule and reduce cost. An Independent Comprehensive Review Panel (ICRP) on JWST, formed at the request of Senator Mikulski, is also under way, and will report to the NASA Administrator

hopefully by 1 October. APS is anxious to see the output of this report and is scheduling a late-October telecon to review it.

A Senior Review of APD's Research and Technology (R&T) program, in part as a response to the NRC/Fisk report, is also being planned. APS has reviewed the charge for the Review, and will be briefed in early 2011 on the progress of the Senior Review before the issuance of the final report.

APS also addressed NASA's relationship to ESA, and has concurred with the APD intention to not pursue a partnership on ESA's PLATO mission. However, APD is considering pursuing a junior partnership on the Euclid mission (similar to the U.S. concept of the Joint Dark Energy Mission; JDEM), whose science goals are similar to some of those of WFIRST (i.e., baryonic acoustic oscillations and weak gravitational lensing). This plan appears to be in concert with the science goals of the Astro2010 report. ESA is expected to downselect its missions in June 2011. NASA will proceed with implementation of WFIRST as recommended, beginning with formation of the Science Definition Team (SDT) this Fall, to begin to understand how best to formulate the mission in the case that Euclid moves forward. NASA SMD has negotiated recently the possibility of contributing 33% to Euclid (as opposed to a previous level of 20%); this translates to \$260M for NASA's share of cost. NASA is also considering having ESA contribute in a similar fashion to WFIRST, allowing for a neutral cost outcome over time. APS supports the NASA plan to continue the option for a partnership on Euclid, and supports a solicitation for possible US participation, but does not endorse an MOU for Euclid at this time. A majority of APS members also felt that NASA should keep its contribution to ESA at a 20% level. It is recognized that Euclid has microlensing as a secondary science goal, but a guest investigator-led, non-dark energy wide-field survey program is not currently planned. APS feels there is only a roughly 50% overlap of goals at this point. APS would also like to review the charter of the SDT for WFIRST.

The Science Committee briefly debated the decision on cost-sharing ratios between NASA and ESA, which Dr. Boss attributed to essentially protecting NASA's bottom line for missions. Pondering whether Astro2010 had supported a leadership role for NASA on Euclid, the Committee left this question to Dr. Roger Blandford.

Astro2010 Report: New Worlds, New Horizons

Dr. Roger Blandford presented an overview on the recently released Astro2010 report. He cited unprecedented community engagement in the formulation of the report, which involved input of 324 white papers, numerous town hall meetings, and over 700 written submissions to the committee. The report was organized around science, infrastructure and program considerations. Science Frontier panels made choices on science prioritization, independently. Science objectives were divided into three categories: Cosmic Dawn, New Worlds, and Physics of the Universe. The report attempted to foster unanticipated discoveries within its recommendations, as well. Cosmic Dawn considered how to develop precision cosmology to look at early universe conditions; missions under this aegis include, for example, JWST and ALMA. New Worlds addressed detection of nearby inhabitable planets, building on Kepler data. Physics of the Universe considered dark energy and dark matter characterization, the epoch of inflation, and testing the general field of relativity in the strong field regime. Infrastructure discussions included a proposal to streamline international long-term strategic planning by holding high-level meetings every 5 years. Astro2010 also recommended that NASA, NSF and DOE request advice from an independent standing committee, essentially an implementation advisory committee to assess congruence with Decadal Survey goals.

In optimizing its recommended program for the resources assumed, the report attempted to prioritize investigations based on science objectives, while also addressing balance between small, medium and large missions; existing facilities and new ventures, promise and risk; ground- and space-based observations; and known science objectives and discovery space. To this end, Astro2010 set up four

panels for program prioritization; most relevant to NASA Astrophysics were Electromagnetic Observations from Space, and Particle Astrophysics and Gravitation. The panels also performed cost, risk and technical evaluations of projects.

As previously described by Dr. Boss, the top priority mission was identified as a large-scale space program, WFIRST, which can open up a new frontier in exoplanet studies with microlensing techniques, when combined with Kepler data. WFIRST can also explore dark energy using three techniques, baryonic acoustic oscillations (BAO), weak gravitational lensing (WGL) and supernovae distances. WFIRST will also survey our and nearby galaxies via a Guest Investigator (GI) program. All WFIRST science goals are deemed possible using JDEM-Omega hardware, with a total cost estimated at \$1.6B. Dr. Blandford commented that the Astro2010 authors were aware of ESA/NASA discussions on Euclid, and had expected that the U.S. would play a leading role in its top priority mission, also noting that a minority role does not appear among the NMWH recommendations. Dr. Blandford refuted some WFIRST misunderstandings, observing that some believe WFIRST to be simply a dark energy mission, or that the ground-based Large Synoptic Survey Telescope (LSST) would suffice for dark energy science (the two proposed telescopes are complementary). Another mistaken belief is that WFIRST would be more ambitious than Euclid, and that therefore WFIRST “can wait.” Other misunderstandings are that WFIRST is a ten-year mission (the Decadal Survey recommended a 5-year baseline). WFIRST was chosen as a top recommendation on the basis of its broad science program, and its low technical and cost risks, among other reasons.

As a second priority, Astro2010 recommended a restoration of the Explorer program to support rapid, targeted science observations. Thirdly, LISA is expected to open up a new field and can support unscripted discovery. The report recommends the U.S. contribute a 50% share, conditional on the success of the LISA Pathfinder mission and selection of LISA by ESA as its L-class mission.

Medium-scale space programs recommended by the Decadal Survey are a New Worlds technology development program, and an Inflation Probe technology program, as well as a U.S. instrument contribution to missions such as SPICA, a JAXA/ESA-led effort. Other recommendations included a future ultraviolet-optical space capability, a ground-based effort with LSST, and mid-scale innovations proposed to NSF, similar to NASA Explorers.

To inform the NASA budgetary context, the report adopted NASA’s description of its existing obligations and used two budget scenarios: constant real-year dollars, and growth at the rate of inflation. The second could accommodate launching WFIRST, augmenting Explorers, starting LISA, making a timely contribution to SPICA, and advancing IXO and developing exoplanet and inflation technology. In summary, the survey presents plans to continue the remarkable program of discovery at an extraordinary time in the study of the cosmos, using a science-driven program supported by international, public-private and interagency collaboration. Dr. Blandford reiterated the need for an independent advisory committee to assess progress in carrying out Astro2010 goals, and acknowledged his colleagues and the astronomical community in its collective effort.

Dr. Tapley called into question the leadership expectation on WFIRST. While acknowledging NASA’s tremendous success with Kepler, he interpreted the implementation of WFIRST within “a” leadership role, and not “the” leadership role, quoting the specific language used in Astro2010. Dr. Morse added an assurance that WFIRST would go forward as recommended, however APD wishes also to consider a cost-neutral program with ESA with respect to Euclid. He averred that APD was not in a position to lead Euclid at a greater than 33% level, especially since ESA had not offered such a share, but instead was pursuing a wide range of approaches to realize participation in a number of projects. In prior discussions with the Decadal Survey committee, APD had provided budget and schedule guidance, including uncertainties associated with JWST. Furthermore, APD had given guidance in September 2009 showing

that any significant budget wedge is unavailable until JWST launches. Dr. Morse felt that it would be prudent to present the community an opportunity to be a minor partner on Euclid, knowing that its science goals are relevant to NASA needs, and knowing that Euclid might complete its 4-year mission before WFIRST launches. Minor partnership participation in Euclid ensures U.S. access to data.

Dr. Blandford responded that Astro2010 had used constant-level dollars, and not Dr. Morse's declining budget, in its deliberations. He further contended that if one accepts that Euclid launches in 2018, and WFIRST launches after 2022, that scenario might undercut the science case for WFIRST. It was therefore not clear that NASA payment into Euclid's mission would be reimbursed. Dr. Morse asserted that WFIRST would need upwards of \$300M a year at peak funding to execute, which is why it is behind JWST. On the other hand, ESA could begin its investment sooner in Euclid. The small NASA investment in Euclid would help spread out cost and leave more budget available for other APD activities. It is not considered a factor in driving the WFIRST launch. Dr. Weiler stated succinctly that whether Euclid flies or not, WFIRST would still launch in 2022; there is no tie between these two missions.

Dr. Turner, citing APS findings on the Euclid partnership, asked whether Dr. Blandford felt that NASA was pursuing a good path forward. Dr. Blandford agreed that much is still unknown about the mission, but felt that Euclid is more ambitious than WFIRST, and that WFIRST is not fleshed out; therefore it does not seem to be the right time to make a binding agreement with ESA. He recommended that the decision be put off until next year. Dr. Morse noted that the 20% assumption in the ESA announcements was done at risk, and that NASA had told ESA that NASA would wait until Astro2010 commented. NASA believes that PLATO is not compatible with its science goal, and would like to put out an NRA to solicit scientists for participation in the Euclid consortium in the meantime to be ready for selection in 2011. Dr. Morse added that he had also informed APS that if Euclid were to be selected, NASA would be happy to engage ESA at a time of greater certainty to discuss a combined mission. For now, Euclid is firmly within the ESA planning framework. He reiterated his assurance that U.S. participation in Euclid is planned to be minor, and that it will not influence ESA going forward with the mission.

Dr. Turner asked, given the concern that a fully robust Euclid would make WFIRST untenable in the U.S., whether waiting a year to see if the two missions could be combined would be a good idea. Dr. Weiler responded that everyone should worry about telling the science community that NASA is not interested in Euclid; if NASA has no involvement in Euclid, ESA will take over the dark energy field. An MOU is at least a year away, but in the meantime, Dr. Weiler firmly asserted that NASA must inform ESA of its intention. Dr. Morse noted that APS supports issuing the NRA. Dr. Boss reported being in violent agreement with the idea that NASA continue to inform ESA that it is interested in the Euclid mission as a partner. Upon closer questioning, Dr. Blandford agreed that NASA should keep its options on Euclid open until June 2011. Dr. Turner also agreed with the recommendation. Dr. Weiler cautioned that NASA is in the position of assuming that it can convince ESA that NASA might take the lead in dark energy at a later time, and that this may be difficult. Dr. Morse agreed with this premise, reiterating that it would be better to integrate at the 20% level now, which will enhance NASA's ability to merge the missions later. He reiterated that it is understood that WFIRST and Euclid are not the same mission. Dr. Weiler expanded on this thought, adding that Euclid does not have a supernovae program, nor an infrared WGL component; therefore any future mission merger will require an effort. Dr. Blandford also suggested that NASA invite Euclid/ESA members to the SDT for WFIRST. Dr. Weiler concurred.

Dr. Turner asked that Dr. Boss convert the relevant APS finding to a recommendation in order to detail its disposition toward Euclid. In referring to the APS finding entitled Reaction to Proposed WFIRST and Euclid Plan, Dr. Boss noted that APS immediately supports two major actions: to get the SDT started, and to have NASA maintain its option for participating in Euclid, and was not sure the finding rises to the level of a recommendation. Dr. Boss supported adding ESA members to the SDT, however. Drs. Tapley and Turner felt that the desired outcome (a combined mission) be made known, to also ensure the cost-

neutrality aspect of APD's planning. Dr. Boss agreed to formulate more specific language for the finding over the lunch hour.

Q&A with the Science Mission Director Associate Administrator

Dr. Weiler, Associate Administrator of SMD, welcomed questions from the Science Committee. He commented on possible outcomes of a Continuing Resolution (CR), which would keep SMD from starting new programs. However, programs under way will continue to be funded. Difficult issues will not arise from an extended CR unless it stretched into the March/May time period, when Earth Science missions will be most affected. Appropriated FY11 funds will be needed for OCO-2, and to speed up Tier 1 ESD missions. A CR would not hinder APD disproportionately, as money for WFIRST would come out of an existing funding line.

Dr. Turner asked Dr. Weiler to comment on Astro2010. He responded by applauding the effort, remarking that Astro2010 is the first Decadal Survey to take cost seriously, helping to get a much better feel for the cost of ambitious missions. He cautioned however that cost estimates cannot be taken too far in assessing missions that are still in "PowerPoint" stage, noting that previous Decadal Surveys had erred on the order of 5-10 times in terms of expected costs. Costs that are good to about 50% are still much better than previous surveys have managed. Dr. Weiler also applauded the report for using the second priority position to call for a reinvigoration of the Explorer program, one of NASA's most important programs for adding balance to both Astrophysics and Heliophysics. Knowing that there is pressure to carry out more investigations, he did not want to over-promise on missions, however. He also hoped that the Heliophysics Decadal Survey would also discuss the importance of the Explorer program.

Dr. Weiler noted that the Planetary Decadal Survey has been given an even stronger admonition to keep costs down; as PSD has more programs than any other division, and at present can only afford about 5 of its 7 program lines. Dr. Tapley and Dr. Weiler mentioned that international collaboration has been successfully incorporated in the Mars program for the Mars 2016/18 opportunities and for Mars Sample Return (MSR). Dr. Turner asked for some comment on Lessons Learned from Astro2010. Dr. Weiler remarked that it had been a thorough process that NASA takes very seriously, in trying to ensure that American scientists get as much science for the dollar as possible. He recognized that the Euclid mission has complicated matters, but that despite the timing, NASA still wants very much to be part of it, to allow scientists to have access to its valuable dark energy data. If Euclid is selected by ESA in 2011, NASA wants to be able to participate and possibly merge the concept into a WFIRST-type mission. Clarity will come with time. He felt that another 5 years would have to pass in order to glean any true lessons concerning this latest survey.

Asked about the possibility of DOE participating in dark energy missions, Dr. Weiler reported having met with DOE, OSTP and OMB, at which time it became clear that DOE must make LSST a priority. Dr. Morse added that APD intends to have an open SDT process for WFIRST and would welcome DOE scientists onto the SDT. The parameters in the JDEM MOU were based on different conditions; for WFIRST, APD anticipates rewinding with DOE and starting SDT in an inclusive way, and leaving the door open for a role later, when the mission is better defined. Instruments will be selected by peer review and competition; Dr. Morse reminded the committee that AOs are indeed open to any proposers. There will be more information on instrument definition at the Astronomy and Astrophysics Advisory Committee meeting scheduled for October 7-8, 2010. Dr. Tapley asked if the measurement requirements for WFIRST were known well enough for an instrument call. Dr. Morse replied that some methodology has been formulated (as in figures of merit), but an instrument AO would not go out without crisp science objectives and a description of the investigation (including a design reference mission). Dr. Turner asked if, upon completion of the WFIRST SDT, NASA would be in a position to present some ideas to Euclid on an equal footing. Dr. Morse felt that Euclid might be ahead on technical requirements, as ESA is currently further along in the planning process than WFIRST; some JDEM concepts might be useful here,

and more importantly, there should be ongoing coordination between the Euclid and WFIRST teams. NASA should do an assessment of what these two missions would look like together or independently. Dr. Weiler cautioned against making WFIRST more complex than already conceived.

Dr. Weiler described a recent bilateral meeting with his Earth science counterpart at ESA (Dr. Volker Liebig), in which the discussion centered mainly on Earth science missions in Europe. ESA and NASA also signed a protocol to form Working Groups to inform long-term planning between Europe and the U.S. ESA's data policy has also become more open, a major breakthrough for Earth science collaborations.

Some minor issues on Mars missions were resolved in real time during a separate meeting with Dr. David Southwood (Dr. Weiler's space science counterpart in ESA) on the same trip. For example, the Ka-band communications capability has been retained for the joint Mars 2016 mission, and the two agencies have agreed that all orbiters sent to Mars henceforth would also serve as communications hubs for surface assets (landers and rovers). ESA and NASA have also agreed to hold bilateral meetings roughly every 6 months.

Public comment period

Dr. Michael Levi, identifying himself as an astrophysicist at Lawrence Berkeley National Laboratories, and a co-investigator on the proposed SNAP mission, commented that ESA does not have the ability to provide near-IR technology for Euclid; only the U.S. has this technology and that is source of NASA's bargaining power with ESA. Dr. Levi urged that NASA refrain from "giving away" its near-IR capability, as once Euclid has been enabled in the near-IR, ESA could move on without NASA participation, which would undermine WFIRST. Dr. Weiler reiterated that the head of ESA's Science and Robotics program has stated both in writing and verbally that ESA will move forward on Euclid with or without NASA participation. Dr. Noel Hinners commented that he hoped Astrophysics could emulate the Mars program in its mission planning.

Chief Engineer's Management Operations Working Group (MOWG) Status

Dr. Hinners presented summary items from a NASA Chief Engineer's MOWG meeting related to SMD mission cost studies. The Working Group was formulated in response to tremendous pressure from the General Accountability Office (GAO), OMB, and Congressional committees, which have taken NASA to task on cost overruns. The intent of the MOWG was to clarify, both externally and internally, how cost decisions take place at NASA. Membership in the MOWG included Tom Young, Joe Fuller and John Klineberg; the latter two were NRC cost study members. The agenda of the July meeting included a discussion of the Aerospace study on the same subject, which is still in progress.

MOWG summary observations

- Formulation (phases A and B) funding and content are inadequately budgeted and focused; a long-standing problem. Why are we still not implementing known solutions?
- The database on cost overruns is extensive; any further studies should include new insights.
- The number and burden of cost reviews are becoming counterproductive.
- There is a need for true independence of cost reviews.

MOWG summary recommendations

- Cost modeling and commitments – is 70/30 probability sufficient? NASA should consider an 80/20 probability and better funded phase A and phase B phases.
- To demonstrate that NASA SMD is sufficiently concerned with cost accountability, NASA should educate the external world (OMB, GAO, Congress) with regard to the NASA mission cost control process.

- NASA should enhance the ability of its technical staff to understand the costing process.

Regarding bullet 2 of the recommendations, Dr. Hinnners noted that Associate Administrator Chris Scolese is working to clarify this perception.

Final results from Aerospace study are due at the end of December, after which time the MOWG will hold a follow-on meeting to present solutions to NASA, GAO, OMB and Congressional committees, in order to create a better environment for understanding the NASA cost process. Asked about the charter of the Aerospace study, Dr. Hinnners described it as highly focused on costing, based on an extensive mission database and interviews of project staff, and as looking mainly at cost overruns, and conformance to committed costs.

Planetary Science Division (PSD) Update

Dr. Jim Green, Director of the Planetary Science Division (PSD), provided an update, reporting also for Dr. Ron Greeley, Chair of the Planetary Science Subcommittee (PSS). Recent science accomplishments include a special issue of *Icarus*, which featured 15 papers on the first and second fly-bys of Mercury by the MErcury Surface, Space ENvironment, GEOchemistry and Ranging (MESSENGER) spacecraft. MESSENGER will enter an orbit around Mercury by March 2011. MESSENGER has performed some mapping of field-aligned currents detected in the magnetosphere, representing the first neutron spectrometer measurements of surface elements such as iron and titanium. Dr. Green reviewed some Cassini results such as the discoveries of shepherding satellites associated with Saturn's rings; and the detection of liquid methane lakes on Titan, the only other body in the Solar System with liquid on its surface). Other Cassini highlights include the discovery of geysers on Enceladus; the imaging of Saturn's ring structure during the equinox, and imaging of Enceladus's tiger stripes, which resemble cracks on Europa. Cassini has also detected evidence of Enceladus's ice geysers creating the E ring at Saturn.

The Lunar Reconnaissance Orbiter (LRO) has detected lobate scarf features distributed around Moon, which are interpreted as evidence that the Moon is cooling and shrinking. In Education and Public Outreach activities, a junior high student detected a cave (a collapsed lava tube) on Mars by studying publicly available Mars Reconnaissance Orbiter (MRO) images.

Responding to an NRC-issued Mission Enabling Report released in January 2010, PSD has begun a review of report-related activities through a PSS working group. A selection of 5 instruments for the 2016 Mars Trace Gas Orbiter is also in work; this Discovery mission has received several dozen proposals. New Frontier Step 2 proposals are due in January 2011. The planetary missions Mars Science Laboratory (MSL), Juno and Grail are becoming a reality; Juno is scheduled to launch in August, Grail in September, and MSL in November 2011. PSD also continues to work the ongoing issue of domestic production of Pu-238, having completed a report with DOE and delivered it to Congress. The dual report had originally included a description of equally allocating costs. Since that time, however, Congressional language has directed NASA to pay for the entire service, thus PSD is looking to see how this cost might be accommodated. Production costs, estimated to be \$90M over a 6-year period, would have a significant impact to the program if the bills are passed in their current form.

The National Academies have provided a new schedule for a Planetary Decadal Survey, planning for a release earlier rather than later. The first draft is complete, and the report is now scheduled to be released to NASA and NSF in late February 2011. Dr. Stephen Squyres will release the report publicly in Houston in early March. The new Survey will help to guide the 2013 budget. PSD's next big events are the EPOXI encounter with comet Hartley-2, after first light from Deep Impact's flyby of Hartley-2 had shown that a tail is developing; 64,000 images will be taken during the EPOXI encounter. PSD will also hold a symposium to commemorate the 50th anniversary of NASA's Exobiology/Astrobiology program on 14 October, at the Lockheed Martin Global Vision Center in Arlington, VA. Dr. Hinnners, Dan Goldin, and

Dr. Squyres will be among the guests. Dr. Hinners asked if the production of Advanced Stirling Radioisotope Generators (ASRGs) were on schedule for Discovery proposals. Dr. Green reported that they are currently in life test mode, and will be delivered in time for the Discovery 12 selections. Asked if the Mars/Planetary program and ESMD were cooperating together, Dr. Green reported that ESMD is developing its own program under an unclear budget profile. As PSD is interested in laser communications, entry descent and landing (EDL) techniques, and aerocapture, Dr. Green anticipated working closely with ESMD to determine requirements for these areas of mutual interest.

Findings and Recommendations Discussion

The committee refined its written findings. Dr. Freilich reiterated an offer to provide a briefing on modeling needs and computational assets for a future meeting, construed as a dual action to both HPD and ESD. Dr. Torbert suggested considering a statement to NAC that computational efforts will be reviewed in more detail for further consideration at future meetings. Dr. Feeley offered to develop wording to this effect. No actions were carried forward from PSS.

The committee reviewed Dr. Boss's rewrite of APS findings, and an endorsement of the Astro2010 Decadal Survey, including a statement that NASA should proceed with the top-priority WFIRST mission, and furthermore should release a Dear Colleague letter soliciting nominations for the WFIRST SDT, to include representation of all 3 WFIRST science areas. Dr. Morse and Dr. Weiler agreed that the WFIRST SDT should work toward developing a WFIRST mission concept by Summer 2011 to ensure that discussions with ESA are based on appropriate and timely information.

The committee further concurred that NASA's options in partnering with the ESA Euclid mission should be clearly kept open, and that if Euclid is selected, NASA should negotiate a joint ESA/NASA mission meeting the science goals of both Euclid and WFIRST. Dr. Turner added that the goal of one combined mission should be made clear, or if not possible, two complementary missions. Dr. Weiler felt more comfortable with the negotiation of a joint program with ESA. As to NASA's role in ESA's PLATO mission, NASA should inform ESA it will not seek a strategic partnership on PLATO.

Dr. Feeley made suggested changes in real time. Dr. Turner recommended including a comment on the Decadal Survey Independent Advisory Committee (DSIAC), which he felt was highly desirable. Committee members agreed that the umbrella for all recommendations is NASA's response to the Decadal Survey. Dr. Feeley took an action to reformat the language under the general response to Astro2010, to circulate for further review.

Final comments and wrap-up

Science Committee members expressed appreciation to Dr. Tapley and Dr. Feeley for conducting a well-run meeting. Dr. Tapley adjourned the meeting.

Appendix A Attendees

NAC Science Committee members

Byron Tapley, University of Texas, *Vice Chair* and Chair Earth Science Subcommittee, remote
Alan Boss, Carnegie Institution, Chair Astrophysics Subcommittee, remote
Noel Hinners, Consultant, remote
Eugene Levy, Rice University, Chair Planetary Protection Subcommittee, remote
Roy B. Torbert, University of New Hampshire, Chair Heliophysics Subcommittee, remote
Michael Turner, University of Chicago, remote
T. Jens Feeley, NASA Headquarters, *Executive Secretary*, on-site

NASA Attendees On-Site

Max Bernstein, NASA Headquarters
Dick Fisher, NASA Headquarters
Chuck Gay, NASA Headquarters
Barbara Giles, NASA Headquarters
Jim Green, NASA Headquarters
Hashima Hasan, NASA Headquarters
Paul Hertz, NASA Headquarters
Deidre Jurand, NASA Headquarters
David Leisawitz, NASA Headquarters
Peg Luce, NASA Headquarters
Mike Moore, NASA Headquarters
Jon Morse, NASA Headquarters
Mike Moore, NASA Headquarters
Marian Norris, NASA Headquarters
Rita Sambruna, NASA Headquarters
Wilton Sanders, NASA Headquarters
Ed Weiler, NASA Headquarters
Greg Williams, NASA Headquarters

Non-NASA Attendees On-Site

Joan Zimmermann, Zantech IT

Remote Participants:

Linda Andruske, NASA Headquarters
Roger Blandford, Stanford Univ.
Randall Correll, Ball Aerospace
Andreas Diekmann, ESA
Fabio Favata, ESA
Christopher Flaherty, NASA Headquarters
Kevin Grady, NASA Goddard

Richard Griffiths, NASA Headquarters
JD Harrington, NASA Headquarters
Ilana Harrus, NASA Headquarters
Clifton Jackson, NASA Goddard
Bethany Johns, AAS
William Jones, NASA Headquarters
Louis Kaluziński, NASA Headquarters
Bradley Keelor, British Embassy
George Komar, NASA ESTO
David Lang, NRC
Michael Levi, LBL
John McCarthy, Orbital Sciences
David McComas, SWRI
Peter Meister, NASA Headquarters
Stephen Merkowicz, OSTP
Michael Moloney, NRC
Jeffrey Newmark, NASA
Malcolm Niedner, NASA Goddard
Saul Perlmutter, UC Berkeley
Linda Rowan, AGI
Donald Shapero, NAS
Abigail Sheffer, NAS
Marcia Smith, SpacePolicyOnline
Ray Taylor, NASA Headquarters

Appendix B
NAC Science Committee Membership

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

Alan P. Boss
Department of Terrestrial Magnetism
Carnegie Institution of Washington

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

Ronald Greeley
School of Earth and Space Exploration
Arizona State University

Noel Hinnert
Consultant
Littleton, Colorado

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

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

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

Roy B. Torbert
Space Science Center
University of New Hampshire

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

Appendix C

NAC Science Committee
September 28, 2010
Virtual Meeting
(WebEx and Telecon only)

Agenda
(all times EASTERN)

Tuesday, September 28

8:30-8:35am	Remarks and Announcements	Tapley, Feeley
8:35-8:50am	Pilot: Open domain publishing	Bernstein
8:50-9:20am	Earth Science	Freilich
9:20-9:50am	Heliophysics	Torbert, Fisher
9:50-10:20am	Planetary Protection	Levy
10:20-10:30am	Break	
10:30-11am	Astrophysics	Boss, Morse
11:00-Noon	Astrophysics Decadal Survey	Blandford
Noon-1pm	Lunch on Own	
1:00-1:30pm	Q&A with AA	Weiler
1:30-1:40pm	Public Comment	
1:40-2:10pm	Chief Engineer's MOWG Status	Hinners
2:10-2:40pm	Planetary Science	Green
2:40-3:00pm	Findings and Recommendations	
3:00-3:05pm	Final comments/Wrap-up	Tapley, Feeley

Appendix D Presentations

1. Open Access for SMD-Funded Research, *Max Bernstein, Paul Hertz*
2. Earth Science Division Update, *Michael Freilich, Byron Tapley*
3. Heliophysics Update, *Richard Fisher, Roy Torbert*
4. Planetary Protection Subcommittee, *Eugene Levy*
5. Astrophysics Division Update, *Jon Morse, Alan Boss*
6. Astro2010: New Worlds, New Horizons, *Roger Blandford*
7. Chief Engineer's Management Operations MOWG, *Noel Hinners*
8. Planetary Science Division Update, *James Green*