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NASA Langley Research Center
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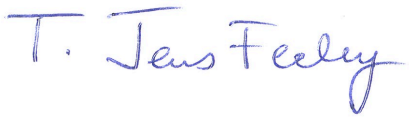
MEETING REPORT

David J. McComas, Chair



T. Jens Feeley, Executive Secretary

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July 28, 2014

Welcome and Introduction

NASA Advisory Council (NAC) Science Committee (SC) Executive Secretary, Dr. T. Jens Feeley, opened the meeting and made administrative announcements.

Dr. David J. McComas, Chair of the NAC SC, opened the meeting, welcomed members, and noted the addition to the committee of new *ex officio* member Dr. David Spergel, Chair of the Space Studies Board. Science Mission Directorate (SMD) Associate Administrator (AA) Dr. John Grunsfeld was present for the first day of the meeting.

Ethics Training (non-FACA portion of meeting)

Mr. Adam Greenstone, representing the Office of the General Counsel (OGC), delivered the annual ethics training for Science Committee members.

Joint Session Science/Human Exploration and Operations Committees

The SC and the Human Exploration and Operations Committee (HEOC) met for a joint session to discuss current programs shared by SMD and the Human Exploration and Operations Mission Directorate (HEOMD), as well as science opportunities within the Space Launch System (SLS) that is currently under development. Dr. Bette Siegel, Executive Secretary of the HEOC made administrative announcements. Members introduced themselves around the table. Mr. Kenneth Bowersox, Chair of the HEOC, introduced himself, and looked forward to learning more about the state of cooperation between SMD and HEOMD.

Dr. James Green, Director of the Planetary Science Division (PSD), presented an overview of how SMD and HEOMD have been making steady progress in working together over the last 6-7 years, and gave a brief summary of their most recent joint activities. The Lunar Reconnaissance Orbiter (LRO), which had been transferred to PSD from HEOMD's predecessor in 2013, is now producing the largest data volume in PSD. The two divisions have also been collaborating on the development of the Asteroid Redirect Mission (ARM), with SMD contributing data on near-Earth asteroids (NEAs) as observed from the Arecibo and Goldstone radar facilities. For Mars missions, joint division activities date back to the early 2000s, including Mars Odyssey and the Mars Science Laboratory (MSL) Curiosity rover. SMD and HEOMD are working together in the planning of the Mars 2020 mission to develop the next-generation Mars Science Laboratory Entry Descent and Landing Instrument (MEDLI) and an *in situ* resource utilization (ISRU) experiment. In the research and analysis (R&A) program, the two divisions share the Solar System Exploration Virtual Institute (SSERVI), which was formerly known as the NASA Lunar Science Institute (NLSI), as well as smaller grants in the Lunar Advanced Science and Exploration Research (LASER) program. There are also working in tandem on ventures in the Lunar Exploration Analysis Group (LEAG), Small Bodies Assessment Group (SBAG) and Mars Exploration Program Analysis Group (MEPAG).

NASA continues to use the Moon as a proving ground for Mars, the ultimate goal of human exploration. LRO objectives are being funded by both sides in determining safe landing sites, providing high-resolution imagery of the lunar surface, building a global geodetic grid, sensing volatiles at the lunar poles, and studying the space environment (energetic particles and neutrons). LRO met all of its objectives for HEOMD, and is now doing ground-breaking research for SMD, which includes stereo imaging for potential landing sites. LRO imaging may pave the way for sample return from the Aiken basin, which could illustrate how material migrates from impacts, and find cold traps where volatiles may accumulate. SMD's Lunar Atmosphere and Dust Environment Explorer (LADEE) carried a laser communications technology demonstration on board, which supported video/audio and data links; the demonstration worked flawlessly and is now being further developed for deep space experiments.

The Space Technology Mission Directorate (STMD) is developing advanced solar electric propulsion (SEP) technologies for the ARM, which is intended to find and dock with an asteroid, under one option will then be moved via SEP into cis-lunar space. Bagging and grappling approaches are being considered to retrieve an object of 50 tons or greater from either a solid 5-8 m asteroid, or a small piece of a larger asteroid. ARM could contribute significantly to the extension of space exploration operations beyond low-Earth orbit (LEO). SMD will play a role in the identification portion of this mission, using both space and ground-based assets to identify and characterize a target object. The Wide-field Infrared Survey Explorer (WISE) mission (now known as NEO-WISE) has been reactivated to provide infrared (IR) identification of near-Earth objects (NEOs), and has done so well in the last 9 months. The Pan-STARRS and LINEAR telescopes are also being used for this effort. A wide range of asteroids have been discovered using these combined assets. To characterize objects, SMD is using radar at both the Goldstone and Arecibo radar facilities. Goldstone can observe over a larger field of view than Arecibo; the two radars can perform bistatic measurements. NASA is currently conducting radar studies of 70-80 NEOs per year, and is collecting data on spin rate, surface density and roughness, and precise orbital measurements. Most recently, NEOWISE found a 370-m object, near-Earth Asteroid (NEA) 2014 HQ_{124}. Bistatic radar measurements yielded an outstanding image of this asteroid.

SMD continues its robotic exploration at Mars, with the intent of eventually merge this pathway with human activity in HEOMD. SMD has carried out a series of campaigns, from "follow the water" to finding habitable environments at Mars. MSL is currently in Gale crater, a pristine area where it is thought that water flowed rapidly at one time, enabling past habitability. The ten-year old Mars Odyssey, orbiter is still working well, although it is showing some signs of age. The Mars Reconnaissance Orbiter (MRO), launched in 2006, is still functioning well. The European Space Agency (ESA) Mars Express works with both satellites to provide data relays. The MAVEN aeronomy orbiter was launched earlier this year to study atmospheric loss at Mars. The Indian space agency ISRO is launching Mars Orbiter Mission (MOM), for which NASA is providing navigation and communications support. The ESA Trace Gas Orbiter is scheduled to launch to Mars in 2016 to measure methane in the atmosphere. The NASA Mars InSight mission is also to be launched in 2016. InSight is a lander platform that will deploy a seismic experiment and a heat-flow experiment that will provide thermal data useful for science and for future human exploration. NASA will provide a key portion of the Mars Organic Molecular Analyzer instrument for ESA's planned ExoMars rover, at a landing site which has not yet been determined, but which will not be above 40 degrees latitude.

MSL's MEDLI enabled NASA to better examine its ablative heat shield material and determined that the heat shield was thicker than it needed to be; this data helped to refine the heat shield design and reduce mass for Mars 2020. The data also better informed the entry profile for the InSight spacecraft. MSL's RAD instrument has estimated that a human trip to Mars will result in an exposure of about 1000 milliSieverts (mSv), over 500 days (long-stay scenario). Ground-breaking science on Mars continues; radar has measured polar ice depth, confirmed the presence of hydrous minerals such as hematite. Delta-like features have been observed on the Mars surface and best-guess estimates of global groundwater have also been made. PSD has made great headway in uncovering ground truth guided by orbiter observations. Strategic knowledge gaps (SKGs) that will be needed to get humans into space are also being filled in: dust size and composition, access to water, extractable resources. Over the last 50 years, landers and rovers have made significant progress in filling in these SKGs, which will help to identify where humans can eventually go on Mars, and survive on the surface.

The Mars 2020 instrument AO received 58 proposals. The analysis has been completed and NASA is close to announcing selected instruments from both US and international partners. Mars 2020 will traverse to a geologically diverse area, core rocks, cache samples, and allow for critical ISRU and technology demonstrations. The mission will examine fine-scale mineralogy, the presence of potential biosignatures, and help prepare for human exploration through ISRU experiments. The landing ellipse for 2020 will ideally be an improvement over MSL capabilities. The MEDLI-2 for Mars 2020 will employ a more extensive set of sensors on the heat shield, and will possess improved supersonic aerodynamics. The first backshell measurements have been made with improved spatial thermal resolution. Precision Mars 2020 landing technologies will include terrain-relative navigation. High-resolution images of the landing site, compared with observations from MRO, will be used to identify landing hazards such as large boulders. Landing site studies are ongoing. The mission is also envisioning an orbiter that carries optical communications (opcomm) for rover-to-orbiter relay, and for supporting a high data rate back to Earth via a direct-to-Earth channel. Opcomm can quadruple the bit rate to 40 kb/s for a raw science data downlink.

In recent R&A activity, NASA has selected 9 teams for Solar System Exploration Research Virtual Institute (SSERVI), to carry out a wide range of research concerning the moon, Mars, and Phobos/Deimos. SSERVI represents a diverse group of science and engineering experts, and was initiated earlier this year at a major forum meeting. The forum was well received and included 250 on-site attendees, and 500 attendees on Webex. Future activities of SSERVI include advancing entry, descent and landing (EDL) capabilities in terms of both precision and mass, and the development of atomic clocks and ion engines. Mars mission activities may include optical communications, high-resolution imaging, and joint rovers or platforms for seismic, weather, and synthetic aperture radar (SAR). SMD is working with HEOMD's Deep Space Optical Communications, looking for a spacecraft host for deep space communication demonstrations; proposals are expected by the end of year.

Dr. Maura Hagan asked how SMD/HEOMD copes with the rise of new SKGs that result from the pursuit of old SKGs. Dr. Green replied that the various analysis or assessment groups (AGs) are grappling with these continually, and help to uncover the surprises; it is an ongoing process. Dr. Mark Robinson noted that few technology demonstrations were being tested at the Moon. Dr. Green replied that the Discovery AO can easily provide lunar opportunities. HEOC member Condon asked whether there were a companion list of ways in which the SKGs will be filled, to include resource assessment, in a manner

such that NASA and international partners can fill these gaps. Dr. Green responded that NASA is using science systems to answer these questions, after which it will design to the answers. Each of the AGs has international participation, and the NAC and its subcommittees regularly receive information through these forums. The goal is to make observations available to the entire community, which thus far seems to be working well, as evidenced by NASA participation with ESA's Trace Gas Orbiter and ExoMars missions. Dr. Harlan Spence asked if any joint SMD/HEOMD resources existed to support Europa exploration. Dr. Green noted that the Space Launch System (SLS) currently under development by HEOMD may help to open the way to the Outer Solar System. Dr. McComas asked which other areas besides PSD are involved in joint activities. Dr. Green reported that the Heliophysics Division (HPD) is involved in radiation environment assessments. Dr. Siegel added that Planetary Protection is also involved, but felt that PSD was currently the major player. Dr. Grunsfeld added that the International Space Station (ISS) is a big part of the cooperation between programs, as it tries to bridge human exploration much more closely to the science side. Dr. Grunsfeld offered to provide a fuller discussion of these activities at future meetings. SSERVI accounts for roughly $13M on a shared basis. MSL studies represent several hundred thousands of dollars per group, ISRU about $30M (the division of these monies are yet to be determined), and MEDLI-2 roughly $32M. LRO was an $800M mission launched by HEOMD, with SMD providing the archiving and data analysis through R&A. The funding runs the gamut. Asked who will manage ARM, Dr. Green reported that PSD will acquire data and provide it to HEOMD for analysis. PSD is managing the Mars 2020 mission, and is also responsible for SSERVI. Mr. Greg Williams, sitting in for Mr. Bill Gerstenmaier, Associate Administrator for HEOMD, added that SMD will be identifying the target, STMD will be responsible for the SEP module, while HEOMD is leading the full concept definition activity. ARM is being run between three directorates, and out of the A suite by Robert Lightfoot. There is also a detailee who is leading mission concept studies. The bulk of the budget is in STMD and HEOMD; a downselect for ARM is due at the end of this calendar year. The directorate in charge of ARM in the future is still to be determined. A secondary payload capability through SLS/Orion is in work, and a Resource Prospector partnership to look at volatiles at the Moon is planned for the 2017/18 timeframe. Resource Prospector will be funded through HEOMD and perhaps international partners.

Space Launch System

Mr. Bill Hill presented an introduction to a briefing by Mr. Steve Creech on SLS. Mr. Creech, Deputy Manager for SLS at Marshall Space Flight Center (MSFC), provided details of the SLS vehicle, the first flight of which is scheduled in 2017. The "Block 1" vehicle will carry a 70-metric ton (mt) payload. The Block 2 vehicle will provide a 130-mt to a LEO needed for Mars missions. NASA is taking an evolutionary approach to SLS development using Boeing (core stage) and ATK (main engines) components. The engine for the SLS core stage is the Space Shuttle main engine; there are 16 of these left over from the Shuttle program. NASA is just re-starting production of these engines. The intent is to evolve the SLS vehicle through 2 stages by increasing the size of the fairing and using either liquid or solid advanced boosters. SLS is on schedule to be available for launch in 2017, with a 5-meter payload fairing. These cargo-launch variants will offer the reliability of a human mission launch and power in excess of any launch vehicle in history.

The SLS program was initiated in 2011 after assessing a number of concepts, with a 5-segment booster already under development. Main engine test-firing as well as the first launch of the Exploration Flight

Test (EFT-1) are scheduled for late 2014. The Critical Design Review (CDR) for vehicle elements is in 2015, while the vehicle CDR is scheduled for Spring 2015, and a hot-fire test in late 2016. The vehicle will be shipped for stacking, integration and launch in 2017. SLS benefits to space science include the greatest mass lift capability ever, the largest payload fairing of any launch vehicle, and high departure energy availability for missions through the Solar System and beyond. The initial SLS configuration will allow an upmass of 70 mt to LEO, with a future capability for 105 and 130 mt, and mass capability means larger payloads to any destination. A case study for Mars Sample Return (MSR) being conducted at the Jet Propulsion Laboratory (JPL) is considering a one-launch mission instead of three launches. SLS offers a single-launch option for MSR; the additional benefits of SLS for MSR include reduced mission time. Dr. McComas asked what the driver was on the huge increase (of payload capacity). Mr. Creech responded that typical Mars payloads for human missions, including habitats and landers, accounted for the payload masses.

SLS is investigating the use of existing fairings for early cargo flights, and is currently in Phase A studies for 8.4 and 10m fairings; these would be useful for Mars missions and monolithic telescopes. A case study being carried out by the ATLAST team at Goddard Space Flight Center (GSFC) is looking beyond the James Webb Space Telescope (JWST) at a large-aperture spectroscopic telescope that may include the ability to service the telescope at L2. The high departure energy of SLS can also reduce the cruise times to the Outer Planets; up to a 4-7 year reduction in travel time to Saturn, for example.

The Europa Clipper mission has served as an early pathfinder for SLS. The mission is currently considering a 5-ton spacecraft to be launched on an Atlas rocket that would work well in SLS Block 1, enabling a direct trajectory, and reducing flight time from 6.5 to 2.7 years and thus return time on science data. SLS has been working on the details of how to design missions, and thus far seems able to accommodate such parameters as variable launch windows. JPL flight designers could answer this. Jupiter is accessible every 13 months, and Mars every 26 months. Mr. Creech noted that the vehicle would also have to carry more fuel to enable orbit insertion at Jupiter. SLS will also provide secondary payload opportunities beyond the current Evolved Expendable Launch Vehicle (EELV) capability (lunar and beyond). A possible next step can be the ARM, as SLS reduces transit time and offers the potential for redirecting a larger object and for enabling a wider variety of targets. NASA could launch an ARM spacecraft as early as 2018/9. Dr. McComas asked how much it would cost SMD to use SLS for Europa. Mr. Creech replied that the goal was to make it cost-neutral. Mr. Hill added that the goal is to get the cost below $500M in order to make SLS competitive with EELVs. Mr. Creech noted that Shuttle flights usually cost SMD about $40M. Dr. Robinson asked whether the program was restarting production of RS-25 engines or replacing them. Mr. Creech replied that the program is still studying options, but will likely modify the nozzle. The Space Shuttle Main Engine (SSME) controller has already been modernized. Dr. Robinson commented that SLS is looking at $200M per launch based on the use of just 4 engines. Mr. Hill noted that SLS is still looking at the production cost drivers to reduce the expense.

Discussion

The committees engaged in a discussion of their joint charter. Dr. Douglas Duncan commented that it would be worth tracking SLS costs with the same specificity as the other science mission requirements; there will be no customers if the cost is prohibitive. Dr. Grunsfeld, described his experience with the Shuttle program, and supported new human space flight capabilities with a science customer in mind. Mr.

Williams noted that the cost of production is being discussed as an agency-wide solution. Mr. Bowersox commented that competing with commercial providers could be a big issue. Mr. Williams observed that the question of competition speaks to what constitutes a secondary payload, and the perceived utility of SLS. Congress may decide that cutting transit time is a relevant issue. Dr. Grunsfeld added that transit time reduction is also a great benefit to program management, as it can save $50M/year in "standing army" costs while a spacecraft travels to its destination. HEOC member Mr. Richard Malow commented that the National Academies of Science (NAS) indicated that a launch rate of one every 3 or 4 years was too infrequent – and that a rate of something closer to one every year – or one every 2 years was critical to sustain the SLS capability. Mr. Hill noted that the current SLS baseline flight rate is one every two years, after the first two launches. HEOMD is also looking at other customers such as the intelligence community. It is physically, if perhaps not monetarily possible, to get to one flight per year. Dr. Spence suggested holding more SC/HEOC joint meetings to tease out more opportunities that are not currently evident in the community; he asked how SMD could tap into SLS in light of all the competing forces. Mr. Hill responded that NASA is just getting into addressing the issue of larger spacecraft and payloads. Dr. Grunsfeld commented that one cost driver of the Shuttle program was the configuration control and safety processes needed for human flight. Dr. Robinson felt that SLS sustainability seemed to be based on a lot of hope, and wondered how the program could be more robust to political winds. Mr. Hill responded that the program was well aware of political considerations and was therefore looking at other applications such as science and intelligence. The biggest concern right now is to sustain SLS through the next Administration change and must demonstrate progress; however it is clear that SLS cannot be sustained on $3B per year. Questions such as the need for active radiation protection during cruise phase for humans have yet to be answered. Dr. McComas requested more detailed briefings about missions from HEOMD in the future.

Center Director Welcome & Joint Committee Discussion

Langley Research Center Director Stephen Jurczyk welcomed the two committees and made brief remarks.

The committees discussed what sort of science applications, could be tested out in HEOMD. Some suggestions included using Stand Alone Mission of Opportunity (SALMON) calls to inject science into the mix. Mr. Hill suggested bringing in STMD as well, such as with SEP. Dr. Steve Running commented that one limit for including synthetic aperture radar (SAR) on Earth Science Division (ESD) satellites is the folding of antennae in preparation for launch; larger fairing volumes could relax constraints on SARs. Dr. Spence suggested holding a workshop that can pull some blue-sky ideas from the community. Mr. Creech noted that SLS is close to publishing a Mission Planner Guide. Dr. Carle Pieters echoed some previous comments on the cost and cadence of SLS, and recommended that future meetings provide an integrated discussion of the long-term cost and budget aspects across the NASA divisions.

Discussion with Associate Administrator

Dr. Grunsfeld welcomed members, thanked them for their service, and addressed various matters with the SC, reminding the committee of the NASA charter, which includes the expansion of human knowledge of the Earth, and of phenomena in the atmosphere and space. He hoped to get an idea of balance from the SC on how to carry out science, and looked to the committee for tactical advice. Dr. Grunsfeld personally felt that the questions of whether we are alone in the universe, and whether life is sustainable on Earth are the

most important. A larger, practical question is how humans affect the Earth. SMD currently supports 94 missions with 120 spacecraft in formulation, operations, and extended operations, representing a diverse portfolio. According to Greg Davidson's *Science News* metric, from 2006-13, NASA science has provided roughly 8-15% of worldwide science news. Half of these data come from extended science missions and the metric illustrates one of the benefits of making NASA data freely available. SMD planning is based on strategic missions such as Hubble, Cassini, MSL/Curiosity and competed missions such as MAVEN. Historically, the missions are pretty balanced and consistent. In terms of SMD disciplines to date, all have been subject to a full cycle of decadal surveys. Dr. Grunsfeld provided details on missions in progress such as Mars 2020 and JWST, and reviewed some budget details. He noted that missions have been doing better on cost/schedule performance based on recent changes, including the adoption in the last few years of Joint Confidence Level (JCL) practices, and that SMD is performing much better cost and schedule estimates on missions. Dr. Spence asked if this trend is expected to continue. Dr. Grunsfeld felt that despite some liens on missions that are having problems, the trend is good. Dr. Green added that LADEE was the only recent mission that had been approved at the 50% level, and its cost rose only due to a prolonged launch delay. There is more competition in the launch vehicle arena, and it is expected that after SpaceX qualifies its vehicles, NASA will have an alternative to the Delta II. Dr. Feeley added that the fact that there is a trend of missions coming in at their predicted cost and schedule estimates is a finding of note, which could be discussed. The guidance for Mars 2020 is $1.9B, including the cost of the launch vehicle. Dr. McComas questioned the overall balance of the program between SMD and HEOMD. Dr. Grunsfeld observed that he served as an advocate for science, while Mr. Gerstenmaier advocated for human exploration. The community needs to look for the best synergy and for areas where SMD can take advantage of the budget. Dr. Duncan noted that most college students believe the NASA budget is ten times larger than it actually is. NASA could do a better job of explaining this discrepancy in perception to taxpayers.

Dr. Grunsfeld addressed the FY15 situation, noting that a budget will probably not be enacted by 1 October. Congress has allocated $5.2B for SMD vs. $4.7B per the budget request. NASA is encouraged that Congress supports science with its appropriations suggestions. Dr. Grunsfeld believed that NASA is the greatest science engine on the planet, and was proud to represent it. Dr. Spence asked how SMD works with the Office of the Chief Scientist (Dr. Ellen Stofan). Dr. Grunsfeld explained that the principal function of the Chief Scientist is to provide advice to the NASA Administrator. The Administrator also has an Executive Council which includes the Chief Scientist and the Chief Technologist, but that does not include the AAs; the Executive Council makes budget and policy decisions at an Agency level. A final Operations Plan for 2014 is still in Congress, which is expected to be released soon, which will help guide the path toward 2015. There will likely be a Continuing Resolution (CR), and the Executive branch will write guidance for NASA; this guidance is usually a combination of the previous and the next fiscal years. During a CR, NASA cannot initiate or terminate programs. There is some internal guidance for preserving projects while budget decisions are under way, and delays are occasionally necessary. Dr. Feeley noted that 1996 is the last time NASA received an appropriation before the fiscal year began. Dr. McComas asked how NASA was interpreting the latest travel and conference guidance. Dr. Grunsfeld noted that Dr. John Holdren of OSTP put out a clarified memo stating that the business of science was not intended to be overly limited by the newest conference restrictions and noting that active participation by government scientists in major professional conferences is integral to their job. NASA is still working on this issue on a practical level. The limits for the upcoming Committee on Space Research (COSPAR)

meeting, to be held in Russia later this year, are affected by political events beyond NASA control. Dr. Grunsfeld recommended that the SC hear a travel briefing from the OCFO or the Administrator's Chief of Staff.

Dr. Spence asked how Decadal Survey and Roadmapping exercises play into strategy and tactics. Dr. Grunsfeld noted that the AGs and Science Definition Teams (SDTs) are helpful with strategizing, and was interested in getting feedback from community once the Mars 2020 instruments are announced. He noted that after 2020, the slate is blank for the next Mars mission. The subcommittees and the AGs can provide some stimulus for thought. Dr. Grunsfeld brought up the biggest issues he felt the SC could address, which were travel and the consolidation and coordination of education and outreach efforts. The new Education and Communications (E&C) group within SMD's front office is developing a plan for SMD to bring Education and Outreach goals forward. Congress is very supportive of maintaining the excellence of NASA science education, which has been a major motivator for US students. Dr. Robinson pointed out the polarized debate surrounding the value of the ARM and wondered if there is adequate science input into ARM, or whether engineering considerations trumped science. Dr. Grunsfeld suggested the SC hear briefings from Michele Gates and Lindley Johnson. The principal function of ARM is to provide some interesting destinations for Orion's first flight. He provided some details of the currently envisioned mission, a component of which is planetary defense. It would be useful for NASA to show if it is possible to deflect an asteroid, as well as to test laser ablation technology. From a science perspective, SMD is providing analysis support, but it must be recognized that ARM is first and foremost an HEOMD mission.

Dr. Grunsfeld addressed proposal win rates, noting that proposal numbers have gone up. He felt the SC should help NASA figure out how to address ongoing R&A concerns, as SMD considers adopting a two-step approach to proposal selection. There are many proposals that are selectable but cannot be selected. Dr. Duncan suggested that NASA examine the way NSF science differs from its education side, where the latter focuses on how the dollars can be used most wisely.

Planetary Science Division/Planetary Science Subcommittee (PSS)

Dr. Green provided an update on PSD. The Planetary Science Subcommittee (PSS) has not met since the last SC meeting, thus there were no findings to report. Upcoming planetary mission events of note include the second anniversary of Curiosity's landing in August 2014. The rover is making its way to Mt. Sharp to examine geological strata. On 21 September the MAVEN aeronomy spacecraft will be inserted into orbit at Mars. Soon afterward, the ISRO spacecraft will enter Mars orbit. In October 2014, the comet Siding Spring will come within 130,000 km of Mars. All assets currently at Mars will have a chance to observe the comet nucleus, which is estimated to have a diameter of about 2 km. In November, ESA's Rosetta spacecraft will land on the contact-binary comet Churyumov-Gerasimenko, where US instruments will make some observations. NASA is also working with JAXA on the Hayabusa 2 sample return mission to a carbonaceous chondrite; NASA will receive about 10% of the sample. MESSENGER will run out of fuel in March 2015; the plan is to have it make observations as it impacts Mercury. In late March 2015, Dawn will insert into its orbit around the dwarf planet Ceres, after having encountered Vesta, the second largest known asteroid body. In April 2015, the Europa step 1 instrument selection will tale place. In July, New Horizons will fly through the Pluto system. In 2016, both ESA and PSD are launching Mars missions, the InSight seismic mission, and ESA Trace Gas Orbiter. In March 2016,

NASA will make step 2 selections for Europa instruments. In July 2016, Juno will enter orbit at Jupiter, and ESA's Bepi Columbo will launch to Mercury. In September 2016, the launch of asteroid mission OSIRIS-REx to the asteroid Bennu will take place. Also in September, Cassini will begin to orbit Saturn between the rings and the planet, and will get a closer look at the magnetic field. NASA is planning to leverage all of these events for public engagement.

Recent accomplishments in planetary science include the imminent October release of a draft Discovery AO. Step 1 proposals will be due late in this calendar year. The Europa Instrument AO was released on 15 July, and proposals are due 17 October of this year. The 2014 Senior Review has been completed and delivered; the report and the response will be posted together. A request for information (RFI) for a commercial buy of a Mars communications asset was also recently released. The Mars Commercial Telecomm RFI is seeking business models for data-relay services, and is also looking at options to upgrade service at Mars beginning in 2020, possibly via optical communications. The RFI is asking for 10-page entries, due 25 August.

Dr. McComas asked Dr. Green to clarify the ramifications of how extended missions are decided upon. Dr. Green agreed to make the budget trade spaces more evident in the next briefing.

Dr. Green expounded on the increased cooperation between PSD and APD, whereby APD has been encouraging more planetary proposals to the Hubble Space Telescope (HST) to look for a new Kuiper Belt object (as a target for New Horizons) and to attempt to observe more Europa plumes. Spitzer operations have been extended for the next two years partially through added funding from PSD for more observation time. The Spitzer and Keck telescopes are soliciting high-priority investigations of Solar System objects, including monitoring campaigns. He noted that the previous observations of Europa plumes were serendipitous, and that amateurs have been reporting that Jupiter's Great Red Spot is shrinking. The Spitzer Warm Mission continues to observing comets and NEOs. The next critical step for exoplanet search is upcoming for PSD, and the division is looking to join with APD's JWST and sync up with its proposal cycle, and take advantage of the IR wavelengths.

<u>Earth Science Division/Earth Science Subcommittee</u>

Dr. Michael Freilich, Director of the Earth Science Division (ESD), provided a status, reporting that the budget remains relatively flat and consistent. Of the total funds devoted to research, applied sciences, technology development and the flight program; 68% of the budget goes into the flight program. This percentage has not changed appreciably over time. The present on-orbit constellation consists of 17 operating spacecraft. The next Senior Review will be in 2015. ESD has been largely on track with its program for several years. The IceSAT-2 mission breached Nunn-McCurdy limits and has been re-baselined inside NASA, and is awaiting Congressional approval; the mission now has a mid-2018 launch readiness date (LRD). All missions to be launched this year, including Venture-class missions, remain fully funded and on schedule. The first mission this calendar year was the Global Precipitation Measurement (GPM) satellite, launched in February. GPM is a joint microwave-imaging mission shared between JAXA and NASA. Rain rate and surface wind speeds over the ocean will be measured over a 900-km swath. GPM contains improved instrumentation compared to the Tropical Rainfall Measuring Mission (TRMM), and resides in a higher inclination orbit, such that it can provide some calibration standards for other orbiting assets. The GPM orbit will also result in more frequent observations, as well

as new abilities to accurately measure light rain, and snow. GPM tracked Hurricane Arthur in both 2-D and 3-D in early July. The Orbiting Carbon Observatory-2 (OCO-2) was successfully launched on 2 July from Vandenberg, recovering the loss of OCO in 2009. OCO-2 aims to understand the role of extended natural sources and sinks of carbon in the Earth system, and determine how much it differs from the volume of fossil fuel emissions. Although human emissions have been relatively stable, only half of the CO_2 that the Earth emits into the atmosphere stays in the atmosphere. This is variable: sometimes all of it stays, and at other times it all escapes. First light for OCO-2 is expected between 6-11 August.

The next two ESD launches on 2014will be instruments to ISS, RapidScat and Cloud-Aerosol Transport System (CATS). RapidScat is a scatterometer that will measure wind speed and direction and will launch on SpaceX's Dragon Trunk in mid- to late September; it will be able to make more frequent observations of rapidly developing tropical conditions than previously possible. In December 2014, CATS will also launch in the Dragon Trunk and will provide lidar profiling and a time-height cross-section of cloud and aerosol structure. CATS will be useful for determining the size of ash plumes, etc. Soil Moisture Active-Passive (SMAP) launches on 5 November. SMAP will employ active and passive L-band radar and is designed to measure soil moisture and freeze-thaw cycles. SMAP is expected to improve local near-term weather predictions for precipitation. John Deere and Monsanto will be also be evaluating and utilizing the data. TRMM's fuel has been exhausted, and its drift-down phase will begin shortly; its remaining orbit lifetime is about 2 years, and passivation will begin when it reaches an altitude of 335 km. TRMM's remaining time will be used to obtain science data, in cooperation with JAXA. ACRIMSAT has not been contacted since December 2013, and no root cause has yet been established. An intent-to-terminate notice has been submitted for the mission; decommissioning will be completed by August.

Dr. Steve Running briefed the SC on the latest proceedings of the ESS, offering the observation that ESD is to be complimented for launching 5 satellite missions in 2014, and for the implementation and success of the Venture-class missions. ESD has also done a good job of supporting the National Climate Assessment. ESS expected the Global Change Information System (GCIS) to be a valuable link between observations of climate impact and supporting geophysical data sets, but noted that it will add demands on ESD for investments in data systems. ESS also observed that ESD is getting more responsibility for continuity of big global data sets, but is not receiving an adequate budget profile for new mission initiatives. The user community has grown considerably; ESD is recognized as a major provider but is not recompensed as such. Earth science data delivery is going to a widening array of users worldwide. OCO-2 will have huge policy relevance. NASA-funded researchers have produced the first high-resolution (30m) global map of forest cover change for 2000-2012; this map will be critical for carbon-trade negotiations. The Global Environmental Observation System of Systems (GOESS) may be sneaking up on the ESD as a progressive responsibility as well as a potentially blind-siding budget item. ESS made other observations on readiness for the next Earth Science Decadal Survey, and also recognized the success of SMAP early adopters program.

ESS recommended that the SC discuss the effective roles of scientists with K-12 students, citing the recent IceBridge classroom participation exercise as a success story. Dr. Duncan noted that there are several decades of research and survey data that support this recommendation. ESS further observed that the Venture-class missions are going well, and that ISS has proven to be a useful platform for Earth-observing sensors. Dr. Spence asked if the data management issue had any potential overlap with NSF's

GeoCube program. Dr. Running felt there was some overlap, but not much. Dr. Feeley reported the establishment of a new *ad hoc* committee on Big Data that will report to SC, and requested nominee names and general ideas for the committee.

SMD Education Discussion

Ms. Kristen Erickson, Director of NASA's Science Engagement and Partnerships office, briefed the SC on her new role in education and public outreach efforts. After controversial education reductions were imposed across all divisions, NASA is now adding back $15M per year. The House and the Senate have appropriated $30M and $42M per year, respectively, across SMD for education; these funding estimates do not include an additional $6M/year for the GLOBE project, an international Earth sciences educational effort. NASA is encouraged by the trend of Congressional support despite the absence of an enacted budget. She briefly described the functions of the new Education and Communications (E&C) office, formerly EPO. Education primarily includes activities that enhance classroom learning in science, technology, engineering and mathematics (STEM) subjects. Communication is three-pronged: media, multimedia products, and public engagement (outreach). SMD is embracing CoSTEM goals that include improving STEM instruction; increasing and sustaining youth and public education in STEM; enhancing the STEM experience of undergraduate students; and better serving groups that have been historically underrepresented in STEM areas.

NASA SMD's refocused approach will be carried out through a competitive selection of educational organizations that use NASA data, products or processes. The Agency is envisioning a cooperative agreement approach, and use FY15 as a transition year. NASA is requesting significant community involvement while making this transition. The National Research Council (NRC) is planning a workshop in early November. A final Cooperative Agreement Notice (CAN) will be released in December 2014, to be on track to award in late 2015. Continued funding for ongoing activities will be requested.

Mr. Duane Brown directs media services and meets with Ms. Erickson on a regular basis. There are also interfaces with social media representatives. Dr. McComas requested an organization chart. Dr. Pieters suggested that E&C organizers might want to look at the SSERVI and LSI virtual linkage models. Dr. Hagan asked how activities will be prioritized. Ms. Erickson replied that activities will follow the recommendations of the Decadal Survey; i.e. through a science-first approach, informed by subject matter experts and science content. Another priority is to reach as many students as possible. E&C has the time and attention of the division directors, who have been meeting to refine the criteria of the CAN. Dr. Duncan recommended including a mixture of mission sizes; NASA now has the assessment experience, so full-time educators and assessors should be inserted into the process early on.

Joint Agency Satellite Division

Mr. Steve Clarke, Director of the Joint Agency Satellite Division (JASD), briefed the SC, first providing background on the division's history. JASD was created in 2010 to manage reimbursable satellite and instrument development performed by NASA. Current projects are funded by the National Oceanic and Atmospheric Administration (NOAA) and focus on requirements for space weather and related measurements. JASD has a unique responsibility to manage the programs and projects implementation on behalf of the funding agencies, oversee Center execution, and represent customers on the HEOMD Flight Planning Board. The JASD has a lean staff of five program executives, as well as "embeds" that provide

matrix support and resource management. Mr. Clarke reviewed commitment dates for a number of upcoming launches. The GOES-R satellite is slated for a 2016 launch date on an Atlas V 541. All the GOES-R instruments have been delivered to the contractor for integration, and four of six instruments are in environmental testing. GOES-R has an aggressive spacecraft integration and test schedule as Lockheed Martin is in the process of consolidating facilities. GOES-R will not be impacted, but there is some risk to GOES-S, with a mitigation plan in place. The Joint Polar Satellite System (JPSS) has its first launch commitment date in the second quarter of 2017. JASD is working closely with ESD on scheduling and coordination. Some challenges exist with the JPSS-1 Advanced Technology Microwave Sounder (ATMS) instrument, but there is a good plan in place to resolve it. The JPSS-1 spacecraft ship date is October 2016. Contract negotiations are complete for the JPSS-2 Ozone Mapping and Profiler Suite (OMPS) and Cross-track Infrared Sounder (CrIS) instruments. The spacecraft Bus Request for Offer (RFO) for JPSS-2 has not yet been issued, while the office works on a follow-on strategy.

JASD is working closely with NOAA and JPL on the Jason-3 mission; NASA is responsible for three instruments. Jason-3 will launch on a SpaceX Falcon 9. The mission completed its Key Decision Point-D (KDP-D) in May 2013. SpaceX launch vehicle readiness and adequate FY15 funding to ensure launch date of March 31, 2015 are two challenges to the mission, which will have its Operational Readiness Review in mid-January 2015. The Deep Space Climate Observatory (DSCOVR), which is carrying two ESD instruments, is scheduled to launch in January 2015 on a US Air Force Falcon 9. The observatory has undergone all its environmental testing and went through KDP-C in August 2013. Because some of DSCVR's instruments are aging and were not designed to undergo multiple vibration and thermal vacuum cycles, the mission has decided to reduce the number of test cycles and spread out the testing. Final testing will be completed in mid- to late 2017, against a new launch date of October 2018. Dr. Running asked why another Advanced Very High Resolution Radiometer (AVHRR) was to be launched, as it had been supplanted by the Moderate Resolution Imaging Spectroradiometer (MODIS) and Visible Infrared Imaging Radiometer Suite (VIIRS) instruments. Dr. Freilich responded that the decision was based on an agreement and trade with EUMETSAT.

The Solar Irradiance Data and Rescue (SIDAR), formerly the Polar Free Flyer, is looking for ride shares. SIDAR is currently in planning mode with the ISS until the FY15 budget is resolved. Mr. Clarke confirmed that the contract for JPSS included data systems and distribution, but that after one year, the ground segment for JPSS is turned over to NOAA. In response to a question from Dr. McComas, Dr. Feeley *et al*. provided some clarifications on how civil servants are reimbursed in JASD.

Discussion of Findings and Recommendations

The SC discussed dates for the next joint meeting with HEOC, and possible findings regarding HEO joint efforts, SLS, ARM science input, and the lingering issue of travel. Dr. McComas felt more detailed briefings would be required before the committee could make findings on travel and ARM. Dr. Luhmann noted that Dr. Grunsfeld had asked the PSS to play a role in evaluating Mars 2020 decisions, which is usually a role for the NRC. Dr. McComas reported having discussed this with Dr. Grunsfeld at some length, and had asked him for more clarification as to what he wants, as it appeared that conflict-of-interest issues were likely to arise. Dr. Luhmann felt that any PSS discussion could not impact the selection (which has already been done). Dr. Hinners agreed that it is too late for the community to weigh in on the 2020 selections, and that the MSL Lessons Learned report had recommended a two-step process,

allowing for vetting before the final selection; this recommendation was evidently ignored. Dr. Spence suggested the SC receive a briefing on proposal rates and the two-step process for the next meeting.

Dr. McComas suggested a positive and encouraging finding for NASA's latest response to education and communication funding, and proposed that Drs. Duncan, Pieters and Robinson write an E&C finding. The SC discussed HEOMD/SMD joint activities and the somewhat "notional" future of SLS. Dr. Pieters suggested a finding on SLS heavy-lift capabilities, citing caution about the budget and the need for an adequate cost evaluation. Dr. Feeley suggested that the SC review the SLS Mission Planner Guide, when it is available, before deliberating on a finding or recommendation. As to a finding on the SC's joint effort with HEOC, Dr. Spence agreed to draft a finding on the developing partnership and the funding of the radiation assessment detector (RAD).

July 29, 2014
Dr. Feeley opened the meeting.

Astrophysics Division/Astrophysics Subcommittee
Dr. Paul Hertz, Director of the Astrophysics Division (APD), provided a status of the division. The Astrophysics Subcommittee (APS) has not met since the last SC, thus there would be no briefing. During the past week, APD celebrated the 15th anniversary of the Chandra launch, and released images of supernova remnants in our own galaxy: Crab Nebula, Tycho, 3C58, G292.0+1.8. The Kepler mission continues to yield data, including the discovery of the first Earth-sized planet in the habitable zone of the star, Kepler 186f. It has taken time to find these smaller planets, as it requires three transit periods to rule out false-positive results. Kepler is just getting to its third year of data. The numbers of habitable planets discovered will help to drive the design of future telescopes. The HST has provided transit spectroscopy of three hot Jupiters and measured the abundance of water; recent observations suggest that either current theories are wrong or that the Solar System may be anomalously wet. Data from SOFIA's FIFI-LS instrument, an integrated field spectrometer, has shown through its imaging of the Orion nebula that it can study dynamics of star formation regions. Integrated field units are the future for new telescopes. FIFI-LS is now available for Guest Observers.

Dr. Hertz reviewed the 18-month-old Astrophysics implementation plan, which lays out a path to follow the priorities of the Decadal Survey. The Astrophysics Roadmap represents a vision for the next 30 years of Astrophysics. The Decadal Survey missions HST, Chandra, Spitzer, JWST, and the Wide-Field Infrared Survey Telescope (WFIRST), the top priority of the most recent survey, toward which APD continues to work. Progress in carrying out these priorities includes an effort to augment the Explorer program to $140M per year by FY16; participation in ESA's LISA Pathfinder and Athena missions; focused technology development for a WFIRST coronagraph; two mission concept studies for exoplanet probes; three balloon-borne investigations supporting the recommended Inflation Probe Technology Development; and increased funding for R&A from $65M to $82M in FY12 and beyond. JWST remains on track for launch in 2018. APD continues to working on WFIRST/AFTA (Astrophysics Focused Telescope Assets) and has both Administration and Congressional support ($56M in FY14), while the FY15 Presidential Budget Request has called out continued investment for preformulation for WFIRST; the division will be prepared to go ahead with a new start if permitted. A recent NRC study on WFIRST/AFTA supports a positive view of its potential science impact and its current mission architecture, with a caveat against cost and technology risks. The WFIRST/ AFTA SDT has issued an interim report; the final report is due in January 2015, at which time the mission will undergo a Cost Analysis and Technical Evaluation (CATE). The SDT baselines a coronagraph for WFIRST, but the coronagraph is not a threshold requirement and remains descopable. Dr. Hertz took an action to provide cost information for WFIRST with and without a coronagraph. A notional schedule for WFIRST/AFTA

and the SDT report should be available for the NRC Mid-Decade Review. The earliest possible new start would be in 2017, as JWST costs begin to ramp down.

APD received 50 proposals for modeling, simulation and theory in a recent WFIRST Preparatory Science ROSES call; reviews and selections will be made later this year. Despite the FY15 budget proposing its termination, SOFIA continues executing its FY14 operations plans including instrument development on both the DLR (German) and US (NASA) sides. SOFIA has been flown to Germany for a heavy maintenance visit for both the airplane and the telescope; NASA and the DLR are sharing costs. A NASA/DLR Working Group has analyzed several scenarios for a path forward, and NASA is currently executing SOFIA's baselined schedule while attempting to re-optimize how to use the aircraft. The House and Senate have proposed $70M and $87M respectively for SOFIA for FY15. HST continues to perform wonderfully and is currently searching for Kuiper Belt objects (KBOs) to provide targets for New Horizons after its Pluto flyby. At least 2 KBOs have been detected; a full search will be underway through August 2014. The New Horizons team thinks there is a 95% probability that HST will find a target. The NICER mission was confirmed in February. NASA delivered flight hardware for the JAXA ASTRO-H soft x-ray spectrometer (SXS) calorimeter spectrometer; TESS is on track for confirmation in the Fall. Small Explorer (SMEX) and Explorer Mission of Opportunity (MoO) AOs are planned for Fall 2014.

The APD R&A program has seen its selection rates decreasing, dropping from 30% to the 15%-24% range. The R&A budget has increased by 20% since 2007, but proposals have doubled during this same interval. One impact is that proposals with a Very Good rating now have a much lower chance of being selected. The average award size has not changed. APD will be working with APS and AAAC to identify ways to increase selection rates. After a Senior Review earlier this year NuSTAR was approved for an extended mission, and other operating missions including Hubble, Chandra, Swift, Fermi, Kepler, XMM, and Suzaku, were approved for further extensions. The Spitzer mission did not receive approval initially, but after a reclama, it was determined that both the PSD and APD could find further use for the mission; thus NASA will not pursue termination after FY14 and will finalize that direction after the FY15 budget is appropriated. This year APD received $26M more than requested, and the extra funds were directed toward $56M in directed funding for WFIRST, so the rest of the Astrophysics portfolio took a ~$20M reduction in the rest of the program. APD redirected some funds from content in order to continue education activities in FY14, which stands at about half the level compared to FY13. APD intends to fund education out of the $15M SMD budget in 2015, rather than out of the division itself. In response to a question, Dr. Hertz reported that PSD will likely commit under $5M per year to the Spitzer extended mission in FY15/16.

The committee briefly discussed the impact of JWST on NASA as a whole, and whether any funding outside of APD had been re-directed toward the mission. Dr. Hertz noted that during 2009-11, the Astrophysics budget was reduced, and within that squeezed budget, JWST overruns were accommodated, after which APD has partially recovered to its historical levels. Dr. Spence asked about how the change in the cadence of the Explorer line during FY14 impacted science. Dr. Hertz explained that the division is actually growing the Explorer program from $140M per year to $160-170M per year in the outyears in order to bring the program up to the desired cadence. While outyears are notional, APD is in the ballpark for 4 AOs per decade in the planning budget. Dr. Duncan asked if APD had a position on restoring education activities. Dr. Hertz replied that APD is working closely with Kristen Erickson in the restructuring of E&C activities, and will implement the new program to leverage HST and other APD assets in education.

<u>Heliophysics Division/Heliophysics Subcommittee</u>

Dr. Jeffrey Newmark, interim Director of the Heliophysics Division (HPD), provided a status report, first noting that the SMD Science Plan now contains language charging HPD with building the knowledge to

forecast space weather throughout the heliosphere. The breadth of observations being taken in the heliosphere indicates a tremendous return on investment. The Solar Terrestrial Probes mission Magnetospheric Multiscale (MMS) has just gone through a budgetary re-plan for a March 2015 launch and is progressing well. The Living with a Star (LWS) mission, Space Environmental Testbeds (SET) is scheduled for mid-2016; Solar Probe Plus (SPP) just received confirmation to fly in July 2018, having successfully retired risks in its thermal protection system. The Solar Orbiter (SOC) Collaboration with ESA is scheduled for 2018. The US will be flying two instruments on SOC and is also providing the launch vehicle (LV). One item to note on SOC is that the ESA-level Critical Design Review is now being pushed back to start in December 2014 with completion in February 2015, although NASA instruments are moving along. NASA is still planning toward an earlier (internal) launch readiness date (LRD) of July 2017 for SOC. The Explorer missions ICON and GOLD are launching in 2017, and are both in phase B studies. ICON has passed its Preliminary Design Review (PDR) milestone, and GOLD will undergo a Fall 2014 PDR.

HPD's suite of operating missions is functioning well overall. RHESSI's expected detector degradation issues continue to be resolved with periodic annealing. The Solar Dynamics Observatory Extreme-Ultraviolet Variability Experiment (EVE) instrument experienced an anomaly in its MEGS-A component in June, which has not been restored. The twin spacecrafts, STEREO, began to experience a high-gain antenna (HGA) overheating problem, as the antenna had been exposed to more direct sunlight than it had been designed for. STEREO will now enter an extended period to off-point the HGA from the Earth; the new position will temporarily affect the data rate during superior conjunction. HPD is confident that the health of the instruments will be maintained; the bad news is loss of science data during the conjunction period, for a little more than a year (compared to an expected 3 months). The division is also developing a new sounding rocket called the Peregrine, which is similar in class to the Black Brant; its first test launch is due in January 2015. HPD manages sounding rockets for all of SMD, which include a number of missions split between APD and HPD.

Accomplishments include the BARREL balloon campaigns in Antarctica, which consisted of two launches of 20 balloons each. BARREL was designed to take measurements that are complementary with the Van Allen Probes. The rockets and range budget is flat but costs are increasing; if one looks at the outyears beyond FY16, there is concern for sustainability. HPD is continuing to work the issue of maintaining a healthy flight rate in the constrained funding atmosphere. There has been significant progress in rocket campaigns, including a RockOn VII educational launch in June. The demonstration flight, SubTec-6, experienced an anomaly on 2 July, which is still being examined. Degradation Free Spectrometers flew successfully on 22 July; this was the second flight this year to observe solar irradiance in the EUV and soft x-ray spectrum. The Wallops Research Range Operations for FY14 includes many reimbursable activities for other divisions in SMD.

HPD is committed to increasing the fraction of its budget to R&A, per the recommendations of the 2013 Decadal Survey. Within the constrained budget, the division is supporting 500 current awards, most of which are three years in length. At present, a total of $63M is devoted to the small competed PI-led research awards. ROSES 2014 solicitations will continue to use a two-step proposal process; extensions have been made to ensure adequate time for reviews. The CubeSat initiative, begun in FY14 and funded at $5M/year, is ongoing, and is managed by HPD for all of SMD. CubeSat is a science-driven, competitive program; this year HPD won the majority of the FY14 new awards, and the Earth Science Division ESD received one new award. In future years, it is expected that there will be general balance among all the divisions of SMD in the CubeSat program. Competed research budget numbers are generally flat; the success rate has been falling.

The division has a path forward to complete the current program as guided by the Decadal Survey. The next step is to rebalance the program to accommodate the DRIVE initiative. HPD cannot carry out the

cadence of the Explorer program within the current budget, but can do so in the outyears. Dr. Newmark reviewed recent organizational changes, including the addition of Ms. Sandra Smalley as Acting Deputy Director, Dr. Elsayed Talaat as Program Scientist, and Mr. Joseph Smith as Program Executive for the Solar Orbiter Collaboration. In response to a question on the constitution of the CubeSat Integration Panel, Dr. Newmark responded that the panel had just recently been formed; SMD Program Scientists from each of the science divisions sit on this panel, as well as representatives from the Space Technology Mission Directorate. Dr. Luhmann asked if there were any effort in HPD to engage in the search for exoplanets. Dr. Newmark noted that there has been discussion, and agreed that Heliophysics science has great relevance to exoplanets. He further noted some recent posters on the subject of coronal mass ejection (CME) effects on exoplanets.

Dr. Hagan, Chair of the Heliophysics Subcommittee (HPS), reported on the most recent meeting of the subcommittee, which is in the process of being re-constituted; only 3 of 9 previous members are continuing beyond September. The HPS has 5 newly confirmed appointees, with 5 more pending. The HPS held a teleconference 17-18 July, during which it heard a briefing from Dr. Ed Deluca on the status of the HP Roadmap; there have been no substantive changes in the Roadmap status since December. The HPS completed the Roadmap review in April and handed it off to NASA Headquarters for copyediting. The final report had been delayed somewhat because the budget assumptions that went into the Decadal Survey were untenable, and subsequently required much struggle and re-grouping to accommodate; the matter was further complicated by changes in leadership at HPD. Dr. Newmark commented that he expected the final report within weeks.

The HPS heard a briefing from Dr. Nathan Schwadron on the LWS Steering Committee report, a document that will advocate for a focus beyond large missions, and for multi-disciplinary multi-agency science centers. The Solar-Heliospheric (SH) and Geospace Management Operations Working Groups (MOWG) also reported out, releasing some draft recommendations for exploring major partnerships with both US and foreign agencies; optimizing investments in CubeSats; reversing the decrease in HP research proposal success rates; and increasing HPD budget transparency to reveal the true costs for SMD administrative overhead items. Dr. McComas commented that the lattermost subject has been brought up repeatedly, underlining its continuing importance. HPS also had an open discussion on the impact of travel restrictions on the business of science, and suggested that NASA remove as many of the restrictions as legally permissible.

Science highlights in Heliophysics included the STEREO observations that reveal the extent of the solar corona up to 12 solar radii (5 million miles above sun's surface). The SPP mission will go to within 4 million miles of the solar surface, and will revolutionize knowledge about the origin and evolution of solar wind. The BARREL investigation looked at large bursts of radiation belt precipitation at dusk, correlating with measurements made by the *in-situ* Van Allen spacecraft. The Wide Area Augmentation System (WAAS) was significantly degraded by a CME in September 2011, which was observed by both STEREO and they Solar and Heliospheric Observatory (SOHO). Asked whether HPD has a liaison to HEOMD, Dr. Newmark reported that this not the case currently, but that the division is working with them actively on CubeSats, space weather science, and in a number of small initiatives. Dr. Lika Guhathakurta added that HEO is active on the Space Weather Committee, and that there is also have an Agency-level Working Group on space weather.

Discussion

Dr. McComas raised the issues of WFIRST coronagraph cost estimates ($1.6 without coronagraph vs. $1.9B with coronagraph) and the history of JWST funding, commenting that his impression had been that over the years, multiple SMD divisions had contributed funds to support JWST overruns. He felt that SMD ought to talk openly about how those offset funds should be used when JWST finally launches. Dr. Robinson commented that it seemed irresponsible to start talking about another new start like WFIRST,

given that large projects such as JWST and MSL had experienced cost control problems. Dr. Duncan encouraged principal investigators (PIs) to be more attentive and resourceful with regard to contractor issues to help keep a check on costs. Dr. Spence noted that the two largest missions that dominate the landscape had the largest revised baselines, and wondered whether the SC should issue another finding on the importance of following the Decadal Survey. Dr. Hagan felt that the more complicated issue is synthesizing all the Decadal Survey recommendations. Dr. McComas returned to the issue of how SMD should plan as JWST rolls off: Is the right answer that all that money goes into APD? Or should it be spread over divisions if and how it came out of them? The community needs to know the facts behind what "tax" JWST imposed on the whole of SMD. Dr. Robinson suggested the funds could be thought of as a loan that NASA must pay back. Dr. Pieters recommended obtaining a transparent look at priorities continually across divisions as funds rise and fall, specifically to accommodate strategic missions. Dr. Luhmann commented that her impression over the years was that each division seems to proceed forward with each Science Plan; jockeying a mixed pot does not seem to be the case. Dr. McComas noted that there is effectively a fifth division's worth of money now devoted to JWST, and that it would be good to determine what is going to be done with it once it is freed up. Dr. Spence took an action to write up a finding on the JWST roll-off.

JWST Status

Dr. Eric Smith provided the current status of the JWST mission, whose main technical challenge remains the Mid-Infrared Instrument (MIRI) cryocooler cold head assembly. The Program Manager watch list includes the FY14 reserves, which are tight, but which are expected to last through the year; reserves will be tight again in FY15, primarily due to the cryocooler consuming a disproportionate share of funding and schedule. Two months of critical path funded reserve have been consumed during this fiscal year, but the schedule reserve remains in in good shape at roughly a year. The program will probably will seek relief on the 20-micron mid-infrared stray light Level 2 requirement. New International Trafficking in Arms Regulations (ITAR) rules may also impact JWST, mostly related to the detailed documentation required when dealing with multiple contractors to ensure compliance (detectors with potential military applications, e.g.). [note- Dr. Smith's briefing was interrupted by a Joint Session with the NAC Technology, Innovation and Engineering (TI&E), returned to the briefing after lunch].

Technical performance metrics for JWST included one red grade for a mid-infrared stray light background issue; the science Working Group has approved relief for the issue; the net result is that it will take longer to make the some long-duration observations. The remainder of the technical performance metrics concern Level one requirements that are either green or yellow. Dr. Smith addressed concerns about Northrop Grumman (NG) deployment timelines, noting that each element of scheduled deployments has a review, with the participation of NASA employees at each review. The observatory deployment design, as measured by NG, includes many different ways to "watch" or measure deployment of the mirrors, sunshield, *et al.* Addressing a question about why JWST is using an Ariane V launch vehicle, Dr. Smith responded that the Ariane V is the most successful, most reliable vehicle in terms of past performance, and that NASA was delighted that Europe could contribute to JWST through this interface.

Technical challenges with the cryocooler hardware were reviewed: the cryocooler compressor assembly (CCA) has a risk in the manufacturing schedule for building the flight unit. Past issue with cryovalves have been resolved. The main issue of late has been with manufacturing errors (e.g., parts having been dropped on floor). Administrator Bolden has been in touch with the NG CEO on these issues. JPL is also sending extra engineers to NG to help oversee the manufacturing process.

Dr. Smith displayed some photos of the CCA, indicating that flight hardware is well along. Some Spacecraft items of note: the output shock for a non-exploding actuator (NEA) was found to exceed its requirement. The NEA was redesigned and is on the way to being fixed in plenty of time. There were two

issues with the star tracker that had to do with a lever arm (a ground testing concern), and also an enclosure around the baffles which affected tracker alignment (due to thermal variations). The tracker will have a cocoon placed on it to make it more isothermal.

There are some schedule reserve issues. The launch load strength requirement for the Unitized Panel Structure (UPS) for the sunshield was not met, and a new manufacturing process was developed to address moisture issues. The Manufacturing Readiness Review (MRR) for a new build of the UPS is scheduled for 8 August. Integration and testing of the Integrated Science Instrument Module (ISIM) continues, with builders swapping out remaining NIR detectors and attaching the cold head assembly. A full-scale engineering unit of the sunshield has successfully undergone deployment testing. The edges of the sunshield were cleanly separated, allaying any fears about trapping heat and raising the mid-infrared background signal. Dr. Smith reviewed the status of the Optical Telescope plus ISIM (OTIS) and the flow of procedures at Johnson Space Center (JSC).

The year 2014 represented the year of manufacturing for the spacecraft, while 2015 will be devoted to assembling the mirror. The mission is still executing to the 2018 launch date within the budget set out in the re-plan. The main challenge continues to be the MIRI CCA, which needs to be ready by March 2016. The ISIM team is in their most challenging portion of the program, and it is going well. NASA has provided two of the three risk analyses requested by the Government Accountability Office (GAO). The GAO had hoped to do an independent cost/risk analysis on the whole program, which it had intended to carry out with NG despite objections. Dr. Robinson noted that he had read the GAO report, which contained many encouraging words. Asked about scheduling, Dr. Smith reported that the program is not using a single integrated master schedule, but rather updates schedules on a weekly basis. Thus far the updates have worked well. One concern, however, is the lack of that improvement in the cryocooler schedule, which must be shipped to JPL in time for testing before integration. JPL and NG are now looking at ways to change the test schedules to accommodate potential delays. Asked about JWST's funding history, Dr. Smith reported that most of the funding for JWST (roughly 70-80 percent) came out of APD and other divisions in SMD, with some funding provided from other organizations outside of SMD. After the meeting, Craig Tupper calculated that about 82 percent came from APD, other divisions in SMD contributed about 10 percent, and some organizations outside of SMD contributed about 8 percent.

Joint Session with Technology, Innovation and Engineering Committee

The SC met jointly with the recently formed NAC Technology, Innovation and Engineering (TI&E) Committee. TI&E Chair Dr. William Ballhaus opened the discussion, and addressed the language of a proposed joint recommendation regarding ways in which NASA might incentivize technology development programs in small- to medium-sized programs such as Discovery and Explorer. NASA traditionally encourages advanced technology, however policy remains unclear on how to administer technology development. Dr. Matt Mountain commented that the Discovery and Explorer programs have evolved to be the most conservative missions that NASA flies, in contrast to their original purpose. There is no current incentive to bring in riskier new technologies. The question is how to incentivize people to take more technical risk. TI&E recommended that the policy and risk posture be re-examined to encourage technology development. Dr. Ballhaus noted that there are existing mechanisms to address this problem, including reserve for a constellation of missions with a recognition that there will be some added risk. The Mars 2020 mission contains some examples of incentivizing some risks. Are Flagships the right model for this approach? Dr. Spence commented that one needs to know what portfolio of instruments is available in order to allow a proposer to consider the trade; alternatively, more dollars could go to a riskier investigator. STMD Associate Administrator (AA) Dr. Mike Gazarik described the decision-making process behind the selection of the Discovery 13 technologies such as Deep Space Optical Communications; *in-situ* resource utilization (ISRU), thermal protection systems (TPS), green

propellant; and high-power solar-electric propulsion, adding that the Discovery 13 call included special Technical, Management Cost and Other (TMCO) treatment for some technologies. These opportunities came about through discussion with SMD and the community with respect to what was needed for some imminent missions and what was ready to go. Dr. Gazarik felt there was an opportunity to change the game, judging by actions already taken on the most recent Discovery AO. Members of the two committees discussed ways to inject more technology into Discovery, such as extending and increasing funding for phase A to see if a team can get to the point to where it can demonstrate ability. Dr. Gazarik felt that this might be a good approach, but high-risk proposals tend to drop out at the TMCO phase. Dr. McComas suggested providing a list of supplemental materials to PIs that they might use. Dr. Ballhaus recommended putting a spectrum of risk and reward into the selection process, and an extended risk reduction phase funded by STMD to drive down risk; the process mechanism would have to be altered to include this. Dr. Pieters asked whether a new technology could be used for mission-critical aspects, or if technology issues should be waived or lessened in a de-scopeable concept. Dr. Ballhaus felt reluctant to baseline new technology without a risk reduction plan or investment. Another option would be to baseline existing technology, but to support a parallel technology that could be implemented at a particular milestone if it reaches the required technology readiness level (TRL). Dr. Robinson commented that there are programs that manage to raise the TRL of certain technologies, but they don't seem to be fed specifically into flight programs while still minimizing risk. Dr. Ballhaus noted that NASA once had robust technology development programs that evaporated during a series of Administrations. Administrator Bolden is now trying to rebuild the front end using STMD for technology push, as well as by funding cross-cutting technologies. NASA is trying to get these technologies demonstrated in the STMD program and thence to flights of all classes. "Faster, better cheaper" went too far, and NASA has been recovering from that philosophy throughout the 2000s. Dr. McComas liked the idea of addressing technology development at the PI level; it's a better way of spending small amounts of money on proportional investments in smaller, critical things- PIs tend to know what these are. Dr. Spence suggested stretching phases A and B as a policy move for PI-led missions, which have a tendency to be proprietary. Dr. Hinners noted that one must assume adequate funding for phases A and B.

The Science and TI&E Committees modified the joint recommendation language. Dr. McComas requested a briefing from Mr. Gazarik at the next SC meeting.

Public comment period
No comments were noted.

Q&A with Administrator Bolden
NASA Administrator Charles Bolden dropped in and addressed remarks to the Committee, relaying his hope that the community can see that NASA is trying to shore up a balanced portfolio in science, and is trying to establish a rigor to maintain science and the cadence of missions. As NASA moves through budget deliberations for 2016, it is also trying to establish a rhythm that allows Flagship missions to move among the SMD divisions, perhaps at a five- or six-year cadence. Referring to AFTA as the most expensive "free gift" NASA has ever had, he added that there will essentially be no difference between WFIRST costs with or without AFTA. The good thing about WFIRST/AFTA is that it will begin to deliver science results as soon as it launches, as opposed to a Planetary Flagship that takes 6-8 years to get to its destination. The Agency wants to be able to get a good, balanced science program with mixes of small, medium and large missions. NASA encourages the community to look for ways to fly more often, with regular frequency. However, missions will require defined endpoints; the community must be willing to turn things off and to move on to the next advanced technology. Dr. Running asked what the NASA strategy will be for maintaining the continuity of global change measurements. Mr. Bolden observed that the LandSat Data Continuity Mission (LDCM) was established to maintain 40 years of data continuity, but that it was not the same LandSat that was originally conceived. LDCM has benefited from new technology. New and better instruments will be more costly. The smart thing to do is to make things

that we can "plug and play" based on legacy applications, which can be done through making land imaging data accessible to the public. NASA wants to make a better product that will be available to more people.

NASA is currently deploying a Technical Capabilities and Assessment Team (TCAT) to determine the workforce distribution at NASA. TCAT is not attempting to reduce employees, but to determine whether NASA staff possesses the skills that are expected by the taxpayer. Dr. Spence asked how the community could move forward in light of the budget challenges. Mr. Bolden responded that it would be helpful to know that in the case of the Planetary Decadal Survey, cost realities were taken into account while proposing missions. NASA will continue to try to maintain a rhythm such that all four communities get treated fairly. He expressed hope that the next big Astrophysics Flagship would not take 30 years, but that more technology development would be necessary. The AFTA telescopes are not flight-ready for WFIRST, and there is still the question of the coronagraph. This will require efficient planning. Getting to Mars with humans is going to require developing capabilities incrementally, on a smaller scale. There is not enough data to answer pressing science questions about climate change, but NASA recognizes that the data must be gathered; OCO-2 will be revolutionary in terms of what it provides in this area. However, NASA must carry out missions within budget and on time, or it will lose support.

Asked about the new Education and Communication initiative, Mr. Bolden felt confident that SMD would step up to the plate. Dr. McComas commented that NASA gets more *pro bono* work from its scientists than it realizes. The Administrator invited more anecdotes about such contributions, adding that in some way, every penny spent at NASA is also spent on Education. Dr. Duncan noted that Google spends 1% of its budget on outreach efforts. Mr. Bolden pointed out that Congress does not permit NASA to "advertise" in this way, but agreed that NASA must recruit, promote, and retain scientists and engineers, particularly women and minorities. NASA has not been doing well at retaining personnel. Dr. Hinners commented that he had suffered through the Saturn V planning years, which amounted to grandiose plans that ultimately fell apart, and asked whether NASA was heading in that same direction with SLS. Mr. Bolden agreed that this was an area of concern, but remained guardedly optimistic that other communities can use a heavy-lift vehicle. There are not enough human exploration missions to sustain SLS at present, but if other communities can use it, it may be viable.

Dr. Hagan liked the idea of increasing the cadence of smaller missions and asked how that scenario might come about. Mr. Bolden felt that mission PIs could be more open to training students, and cited the Europa Clipper concept as a creative way to answer science questions at a greatly reduced cost. Dr. Pieters felt that a new, revolving approach to Flagship missions would require a paradigm shift, such as the establishment of a 20-year NASA vision statement. Right now all the surveys are arguing for their own Flagships, while smaller missions are still needed to carry out science and technology development. Mr. Bolden agreed and commented that the community can't let budgets drive strategy. He closed his remarks by expressing his support for the community in its efforts to develop a viable strategy to carry out scientifically valuable missions.

Discussion

Dr. McComas returned the discussion to two potential findings on education at NASA, and a JWST funding "roll-off." Dr. Duncan made several observations based on survey findings that indicate students learn best when a teacher is enthusiastic about teaching students, as well as when a teacher is enthusiastic about the subject matter. Dr. Robinson supported the concept of having engineers, scientists and PIs use their free time to interact with students. Dr. Duncan felt it was the duty of a mission PI to provide this type of service to the taxpayer, and commended NASA for holding its workshops for new university/college teachers over the last 10 years. Dr. Running cited NASA's support of GLOBE as another valuable example, and that animations of global data sets have been a tremendous help in this educational initiative.

The committee then reviewed a finding on JWST funding wedge, potentially requesting that the SMD AA assess the relative contributions toward JWST, and a strategy for optimizing post-JWST SMD science within available resources, relative to the Decadal Survey and a balanced program.
Dr. McComas adjourned the meeting at 2:38 pm.

Appendix A
Attendees

NAC Science Committee members
David J. McComas, Southwest Research Institute, *Chair*
Douglas Duncan, University of Colorado at Boulder
Maura Hagan, NCAR, Chair, Heliophysics Subcommittee
Noel Hinners, retired (via Webex)
Janet Luhmann, UC Berkeley, Chair, Planetary Science Subcommittee (via Webex)
Carle Pieters, Brown University (via Webex)
Mark Robinson, Arizona State University
Steve Running, University of Montana
Harlan E. Spence, University of New Hampshire
T. Jens Feeley, NASA Headquarters, *Executive Secretary*

NASA Attendees
Marc Allen, NASA Headquarters
William Ballhaus, NAC
Steve Creech, NASA Headquarters
Elaine Denning, NASA Headquarters
Amir Deylami, NASA Headquarters
Michael Freilich, NASA Headquarters (via Webex)
Kathleen Gallagher, NASA Headquarters
Michael Gazarik, NASA Headquarters
James Green, NASA Headquarters
Mike Green, NASA Headquarters
John Grunsfeld, NASA Headquarters
Lika Guhathakurta, NASA Headquarters
Paul Hertz, NASA Headquarters (via Webex)
David Miller, NASA Headquarters
Jeff Newmark, NASA Headquarters (via Webex)
Yvonne Pendleton, NASA Headquarters
Steve Sandford, NASA LaRC
Eric Smith, NASA Headquarters

Non-NASA Attendees
Michael Johns, SRI
Matt Mountain, Space Telescope Science Institute
Jim Oschmann, Ball Aerospace
Angela Clark-Williams, Zantech IT
Mary Ellen Weber, Stellar Strategies
Ana Wilson, Zantech IT
Joan Zimmermann, Zantech IT

Webex Attendees
Gale Allen, NASA Headquarters
Louis Barbier, NASA Headquarters
Art Charo, National Research Council
Ann Delo, NASA Headquarters
Jeff Foust, The Space Review

Hashima Hasan, NASA Headquarters
Hussein Jirdeh, Space Telescope Science Institute
Greg Lee, Northrop Grumman
Dan Leone, Space News
James Lochner, USRA
Michael Maloney, National Research Council
Jim Manning, Unaffiliated
John Mather, NASA GSFC
Harry McSween, University of Tennessee-Knoxville
David Millan, Unaffiliated
Amaya Moro, Science Institute
Abigail Sheffer, National Research Council
Denise Smith, Space Telescope Science Institute
Gerald Smith, NASA Headquarters
Marcia Smith, SpacePolicyOnline.com
Ellen Stofan, NASA Headquarters
Mitch Watkins, Space Telescope Science Institute

Appendix B
NAC Science Committee Membership

Dr. David J. McComas
Southwest Research Institute (Chair)

Dr. Douglas Duncan
University of Colorado

Dr. Maura Hagan
National Center for Atmospheric Research

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

Dr. Eugene H. Levy
Rice University

Dr. Janet Luhmann
University of California, Berkeley

Dr. Bradley Peterson
Ohio State University

Dr. Mark S. Robinson
Arizona State University

Dr. Steve Running
University of Montana

Dr. David Spergel
Princeton University (ex *officio member)*

Dr. T. Jens Feeley
Executive Secretary

Appendix C
Presentations

1. Human Exploration Operations and Science Mission Directorate Joint Activities; *James Green*
2. NASA Space Launch System; *Steve Creech*
3. Science@NASA; *John Grunsfeld*
4. Planetary Science Update; *James Green*
5. NASA Earth Science Division Update; *Michael Freilich*
6. NASA Science Mission Directorate Education Discussion; *Kristen Erickson*
7. Joint Agency Satellite Division; *Steve Clarke*
8. Astrophysics Update; *Paul Hertz*
9. Heliophysics Update; *Jeffrey Newmark*
10. James Webb Space Telescope Program Office; *Eric Smith*

Appendix D
Agenda

NAC Science Committee
July 28-29, 2014
Langley Research Center
Building 2101, Room 105A&B
Agenda (all times EASTERN*)

Monday, July 28

8:00am-8:10am	[non-FACA] Administrative Remarks – J. Feeley/D. McComas
8:10am-9:10am	[non-FACA] Annual Ethics Briefing – A. Greenstone Call-in Number: 866.735.5143//Passcode: 1773121 Webex: https://nasa.webex.com/ Meeting Number: 996 180 400 Meeting Password: SGE@July28
9:10am-9:30am	**Location change** *Make way to Room 305 (same Building)*
9:30am-1:10pm	Joint Session Science/Human Exploration and Operations Comm. Location: Building 2101, Room 305 Call-in number 844.467.6272//Passcode: 844408 Webex: https://nasa.webex.com/ Meeting Number: 391 017 307 Session Password: HEO-072814
9:30am-9:40am	Opening Remarks – J. Feeley/B. Seigel & D. McComas/K. Bowersox
9:40am-10:40am	Current Joint Programs – Green
10:40am-11:20pm	SLS Capabilities and Plans – B. Hill
11:20pm-12:00pm	Joint Discussion of Findings and Recommendations
12:00pm-12:10pm	Center Welcome & Remarks – S. Jurczyk
12:10pm-1:10pm	**Joint Lunch**
1:10pm-1:30pm	**Location change** *Make way to Room 105A&B (same Building)*
1:30pm-2:15pm	Discussion with SMD Associate Administrator – J. Grunsfeld
2:15pm-3:00pm	Planetary Science / PSS – J. Green / J. Luhmann
3:00pm-3:45pm	Earth Science / ESS – M. Freilich / S. Running
3:45pm-4:15pm	Education & Communications – K. Erickson
4:15pm-4:45pm	JASD – S. Clarke
4:45pm-5:45pm	Discussion/Findings and Recommendations

5:45pm-5:50pm	Wrap-up – J. Feeley /D. McComas
5:50pm	**Adjourn**
6:30pm	Dinner: Surf Rider Blue Water (Hampton) 1 Marina Road Hampton, VA 23669

Tuesday, July 29

8:00am-8:10am	Administrative Remarks – J. Feeley/D. McComas
8:10am-8:55am	Astrophysics / APS – P. Hertz / B. Peterson
8:55am-9:40am	Heliophysics / HPS – J. Newmark / M. Hagan
9:40am-10:20am	Discussion
10:20am-10:30am	**Break**
10:30am-11:00am	JWST – E. Smith
11:00am-12:00pm	Joint session Science/Technology, Innovation & Engineering (TI&E) Committee (in our room)
12:00pm-1:00pm	**Lunch**
1:00pm-1:05pm	Public comment
1:05pm-2:40pm	Discussion/Findings and Recommendations
2:40pm	**Adjourn**
2:40pm	**Location change** *Make way to Reid Conference Center, Langley Room (see map)*
3:00pm	***NAC All Hands Meeting*** *Location: Reid Conference Center, Langley Room*

Telecon & WebEx Information:
Any interested person may call the USA toll free conference call number 888-946-7610, passcode Science, to listen to this meeting by telephone.

The WebEx link is https://nasa.webex.com/
The meeting number for Monday is 998 733 005, and the password is SC@July28
The meeting number for Tuesday is 994 586 911, and the password is SC@July29

* = Flexible Timing; the Chair and Executive Secretary advise observers to continually monitor the meeting with the understanding that session starting times may vary up to ±30 minutes from the times shown here.