NASA Advisory Council (NAC)
Meeting of the
Human Exploration and Operations
Committee

NASA Headquarters, Washington, DC

March 6-7, 2012

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Meeting Report Prepared by:
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Meeting of the NAC Human Exploration and Operations Committee

March 6-7, 2012
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Washington, DC

Committee Members
Present
Chair: Mr. Richard Kohrs
Co-Chair: Mr. Bohdan Bejmuk
Dr. Pat Condon
Mr. Joseph Cuzzopoli
Dr. David Longnecker
Mr. Bob Sieck
Executive Secretary: Dr. Bette Siegel
Administrative Officer: Ms. Shawanda Robinson

Absent
Ms. Nancy Ann Budden
Dr. Leroy Chiao
Mr. Tommy Holloway
Mr. Richard Malow*
**participated via teleconference March 7*

Other Attendees
Brad Carpenter
Steve Clarke
Dan Dumbacher
Michele Gates
Chris Gilbert
John Hinkle
Jacob Keaton
Bill Mackey
Michael Palinkas
Rebecca Sharek
Charles Smith
Kim Terrell

March 6

Welcome and Call to Order

Dr. Bette Siegel, Executive Secretary of the Human Exploration and Operations Committee (HEOC), called the meeting to order and explained that this was an open NASA Federal Advisory Committee Act (FACA) Committee. Committee members were responsible for recusing themselves if they have a conflict of interest. The public was to have an opportunity for comment on the second day of the meeting.

Mr. Richard Kohrs, HEOC Chair, said that the Committee has paperwork in the system to add a couple of additional members. HEOC was to have a closed session for ethics training that afternoon. Committee members in attendance would have an opportunity to meet the new chair of the NASA Advisory Committee (NAC), Dr. Steven Squyres, during the closed session. HEOC last met on October 31 and November 1 2011, but there was no NAC meeting after that. Therefore, some of HEOC's recommendations did not go forward due to the previous NAC chair's term expiring. The next HEOC meeting will be in July and Mr. Kohrs suggested having it at one of the centers.

Mr. Bob Sieck described the 50th anniversary celebration of astronaut John Glenn's historic space flight. Over 200 people attended, and Mr. Glenn thanked the workers who made his mission possible.

Status of the Human Exploration & Operations Mission Directorate

Mr. William H. Gerstenmaier, Associate Administrator for NASA's Human Exploration and Operations Mission Directorate (HEOMD), provided an overview of Directorate activities. He gave the HEOC members a handout describing the 2012 goals for the Directorate and its nine divisions (http://www.nasa.gov/pdf/626738main_HEOMD2012Goals.pdf). There is currently a lot of activity in connection with the International Space Station (ISS). Mr. Gerstenmaier hopes to engage the public in why NASA does exploration and the compelling need for it. He also wants to move the Space Launch System (SLS), Multi-Purpose Crew Vehicle (MPCV), and Ground Systems Development and Operations (GSDO) forward to deliver on cost and on schedule.

There were 14 flights to ISS in 2011, though one was unsuccessful. Fifteen are planned for 2012, including commercial and Soviet launches. An Automated Transfer Vehicle (ATV) launch has been delayed by a couple of weeks. The SpaceX demonstration flight is still scheduled for April 30, but there is a lot of software work that must be done first. NASA has issued documents on the benefits of ISS and the research being done.

In the area of Soyuz anomalies, the 30S was over-pressurized by the Russians, who were very open about this and contacted NASA immediately with information about their plans. They spotted a bulge and a leak, and while initial speculation in the press was that it was a welding issue, it soon became obvious that it was a problem with materials and with the regulator. There was a 2-week slip to the next launch, but now they are on a normal schedule and resumed crew rotation. They have worked with NASA in setting launch dates, and the relationship is better than in the past.

NASA and the Federal Space Agency of Russia (Roscosmos) have a contract agreement, and currently Roscosmos is providing Soyuz vehicle crew seats and Progress vehicle cargo transport. NASA also uses bartering capability actively with all ISS International Partners. Regarding cargo, the ISS will likely be fine through mid-2013 with existing international vehicles. NASA hopes to get a US cargo provider to ISS well within that timeframe, and a US crew service provider is likely by 2017.

In discussing the Launch Services Program (LSP), Mr. Gerstenmaier mentioned that there are not a lot of missions launching in 2012. The Nuclear Spectroscopic Telescope Array (NuSTAR) was scheduled to launch in late March, but that date was in question due to software issues. There has been a great deal of discussion about medium-class missions, and LSP has established a plan with the Science Mission Directorate (SMD) to launch several of these missions in the future. There have also been discussions about the best way to certify new launch missions for SMD payloads. They are acceptable for ISS cargo, and it is possible that NASA could learn something on cargo flights that could help on SMD payloads. Launch Vehicle (LV) expenses drive up a lot of SMD's mission costs. Orbital Sciences (Orbital) and NASA have identified the most likely cause of the failure of the Glory LV, but work is continuing on this.

Mr. Gerstenmaier next discussed the Exploration Systems Division (ESD). The testflight of Orion MPCV will launch in 2014. This is a unique contract in which NASA will not take ownership of the vehicle but instead receive testing information and data. This approach saves NASA the costs of moving hardware back and forth. The resulting test data will flow directly into critical design review for Orion. NASA provides the Missions Operations Directorate (MOD) control and communications with the vehicle, and will see the fairing separation sequence and heat shield and parachute performance information, which are Orion's highest risks. Orion will be launched on a Delta IV and will use a dummy service module and external skin. There will be some radiation sensors on board to measure the internal radiation environment as Orion passes through the Van Allen belt. NASA wants the data for the Critical Design Review (CDR) to support the high risk elements. There will be a fully-functional launch abort system, but

the actual launch abort sequence will be simulated during a later flight test, along with the aero-shield separation. The mission will fly a Low Earth Orbit (LEO) heat shield design and test the adapter, which will be used on SLS. The Delta IV launch environment is still within its design capabilities of Orion. Mr. Dan Dumbacher of NASA explained that the launch will use the Delta upper stage to insert the vehicle into upper orbit. Mr. Gerstenmaier added that representatives of Lockheed-Martin could attend a future meeting to explain this further.

In the area of Commercial Crew Development (CCDev2), there are four funded partners: Boeing, SpaceX, Blue Origin, and Sierra. For an additional three unfunded partners – United Launch Alliance (ULA), Alliance Techsystems Inc. (ATK), and Excalibur Almaz Inc. (EAI) – NASA provides data but not funding. All seven of these companies are in the Element Design mode for FY12, and more than one will enter Integrated Capability Mode in FY13. Certification will follow.

Entering into a fixed price contract in this budget environment is a bad idea, so NASA is not doing that. Mr. Gerstenmaier acknowledged that HEOC is on record against fixed price contracts, noting that NASA has asked providers to see what they can do with schedules and milestones. As for down selecting further, NASA has a lot of flexibility with the Commercial Crew Program and can carry two to four companies at the various levels. The competitions are open to everyone.

The Mars Science Lab (MSL) was launched on November 26, 2011 There are two payloads on board that were developed by Advanced Exploration Systems Division (AES): the Radiation Assessment Detector (RAD), and the Mars Science Lab Entry, Descent, and Landing Instrumentation (MEDLI) sensor suite. RAD is carried on the MSL rover, and it will characterize the Mars surface radiation environment to assess the risks to future human explorers. MEDLI consists of sensors on the MSL heat shield that will measure temperatures and pressures during Mars atmospheric entry to validate models for the design of future entry systems. Both payloads have been powered on during the cruise to Mars, and they are returning data. RAD has detected the large solar particle events that have occurred recently. MSL will land on Mars in August.

The Space Communications and Navigation (SCaN) Division just completed spacecraft thermal vacuum testing for Tracking and Data Relay Satellite (TDRS) K and is on schedule to launch in December from Kennedy Space Center (KSC). SCaN is also deploying new antennae for an upgraded network. In addition, a new radio is going up with new software that provides great flexibility.

In discussing the human spaceflight capability status, Mr. Gerstenmaier said that the goal is to implement ways to reduce costs in commercial space and non-space industries through the use of assets unique to NASA. As part of this effort, the Michoud Assembly Facility (MAF) is using Space Act Agreements (SAAs) with over 20 tenants, building the Orion test capsule, and bringing in other commercial companies. The rocket propulsion test stands are mothballed for 1 year to make them available to organizations that might need them. NASA recently received the National Research Council (NRC) report on Human Space Flight Operations (HSFO) planning for the post-Shuttle era, and it was very supportive in its recommendations. NASA is selecting the new astronaut class of 9 to 15 candidates from over 6,300 applicants. Finally, Mr. Gerstenmaier discussed the Education and Public Outreach (E/PO) activities of the Mission Support Services Offices (MSSO), noting some of the articles and videos that have been released.

Discussion

- *Mr. Joseph Cuzzupoli* expressed concern about both commercial contractors slipping the schedule. He asked what authority NASA has to deal with contractors who are late. *Mr. Gerstenmaier* said that such contractors receive a penalty for being more than 30 days late.

However, NASA may seek the penalty as barter instead of cash, such as asking for additional testing.

- *Dr. Pat Condon* asked for clarification of the definition of "meaningful missions." *Mr. Gerstenmaier* said that NASA wants to avoid establishing a grand plan that the vehicles cannot support. Instead, the Agency is conducting a lot of research to see what can be done, and what the capabilities are. This is a year of preparation, to develop a sound understanding. It might be possible to put forth a plan next winter.

- *Mr. Bohdan Bejmuk* asked if NASA is trying to determine the new reference missions for exploration and if they differ from those for which Orion is designed. Accommodating different reference missions is expensive. *Mr. Gerstenmaier* explained that NASA has looked at the Orion environments and determined that it will be costly if they change. A lot of early missions should be below margin. If there are problems with certification, NASA can back off, but there is no plan to change the Orion contract. For SLS, NASA has defined Level 1 requirements. The Agency is looking at what the vehicles can do, then designing to that, instead of designing missions and designing vehicles to the mission. NASA does not have the funds to redesign vehicles.

- *Mr. Kohrs* observed that there are a lot of options. *Mr. Gerstenmaier* agreed, explaining that this provides NASA with some flexibility should there be problems. The Agency does not want to spend a lot of money on changing contracts.

Capability Driven Roadmap

Dr. John Olson, Director of the Strategic Analysis and Integration Division, explained that national space policy goals have been the fundamental driver of the roadmap, charging NASA with doing the following:

- Energize competitive domestic industries;
- Expand international cooperation;
- Pursue human and robotic initiatives;
- Follow a "flexible path" approach to space exploration, opening up opportunities such as near-Earth asteroids (NEA), the moon, and Mars.

The NASA Authorization Act of 2010 states that NASA is to expand human presence beyond LEO to advance overall knowledge and conduct human exploration. Therefore, first among NASA's strategic goals is to extend and sustain human activities across the solar system. The international community has an interest in the moon, and NASA Administrator Charles Bolden has said that NASA will focus on missions to Mars.

Dr. Olson presented a brief summary of the history of human space exploration, along with the goals for the future. Current objectives show a preliminary plan of 2017-21 for initial missions, which is very viable. The baseline mission in the budget is an uncrewed circumlunar flight in 2017, followed by a crewed mission in 2021. NASA has studied a number of promising locations in cis-lunar space, which indicate a potential ability of the Orion exploration vehicle launched on the SLS to transfer between L1 and L2.

The members of the International Space Exploration Coordination Group (ISECG) share many common goals. The International Objectives Working Group has examined both tangible and intangible goals. For example, one of the tangible benefits is the economic multiplier effect, and an intangible benefit is the extension of human activities across the solar system. While these reflect NASA's mission statement,

each international space agency partner needs to achieve its own goals and priorities. In the incremental expansion of human exploration capabilities, Mars is the destination. There is more than one path to Mars, and therefore the current plan foresees a number of incremental steps to extend human spaceflight capability to enable missions to Mars. Lay audiences often do not understand the differences in the distances between ISS, the moon, and Mars.

Regarding the costs of SLS and MPCV, NASA has performed cost analyses to the subsystem level. At the current level of funding, NASA cannot afford to develop additional exploration elements on its own. As NASA looks at collaboration with other U.S. and international agencies, it has been necessary to descope the program in order to be affordable and executable. For one set of designs, NASA has produced design reference mission (DRM) information. Affordability is a key driver. NASA is investing in and evolving capabilities for avionics and other elements, lowering costs by taking a building block approach. NASA has refined the concepts, identifying what is viable and what can be done early on. Recent work has focused on leveraged use of the ISS.

Dr. Olson showed a table of exploration elements required to perform a number of incremental steps: L1/L2, Lunar surface, Asteroid, Mars orbit, and Mars surface. The table included the capabilities, elements required to arrive at the destination, elements necessary to work there, and the elements needed for return. NASA tracks both time and costs for these elements, as well as phasing and readiness. The Agency has discussed architecture with four different contractors, and is trying to be rigorous in cost estimation.

A figure showed the existing capabilities and those that require development. NASA is expanding its efforts for the Environmental Control and Life Support System (ECLSS), and looking at reducing consumable logistics. The Agency has learned that, for all but the longest duration missions, it is better to bring along more consumables.

Key findings from multiple analysis cycles indicate that it is important to look at multiple DRMs to understand which cases drive requirements. Payload volume is an issue for more complex missions. Heavy-lift launch vehicles have a clear advantage in this respect. Regarding the expensive testing of the Orion, NASA has an Orion program reference with people who participate in all of these teams. The Agency is reinforcing this at the program level. Overall, NASA is trying to do as much as possible while being pragmatic.

Discussion

- *Mr. Cuzzupoli* said that messages he hears about NASA's mission are inconsistent. He said that *Dr. Olson* mentioned the moon, an asteroid, and Mars, but Administrator Bolden and President Obama each say something different. It is confusing for the public. *Dr. Olson* explained that there is no single direction or destination. NASA is developing a set of capabilities for multiple missions that include missions to the moon, Mars, and an asteroid.

- *Dr. David Longnecker* said that the way NASA presents this, it comes across as though the major initiative is to build a lot of flexibility and capability to use many different ways. The Nation and NASA employees might get behind it more if NASA said that the goal is to eventually go to Mars, and there are a lot of steps to get there. That would enliven the U.S. public, which the flexible path does not do. Referring back to Slide 6 in his presentation, *Dr. Olson* said that that is what NASA is doing, and the slide shows where NASA has been and where the Agency is going. NASA also gets feedback that Mars is a dream and that the Agency needs to do something in the near term. Addressing the full spectrum of possible missions answers that comment. *Dr. Longnecker* agreed that it was a great slide. However, the discussion is usually that NASA is

building capability, not trying to achieve a goal. Articulating the goal could help people understand. *Mr. Sieck* added that if NASA said Mars is the destination, people would say that it is a dream. If the Agency said it wanted to go to the moon, they would say that we have been there. *Dr. Olson* said that the capabilities framework helps make NASA a bit more immune to political uncertainties. There are supportable budgets for these scenarios, reflecting strict design-to-cost requirements. Unachievable dreams will not put NASA anywhere toward a robust execution. The Agency is always being asked for sensitivities, what can be done with more or less funding. Being able to show priorities according to funding helps NASA quantify the ramifications of policy decisions

- *Dr. Condon* asked whether Slide 6 could be made available to the public. He had an issue with the description of the 1957-75 timeframe. It does a disservice to what was learned about the human body living in space and what was found on the moon. It does not indicate anything about working on a body near Earth – the moon. *Dr. Olson* agreed that it should change. *Mr. Bejmuk* added that he would replace "learning" with "achievement." NASA went to the moon and to LEO, and learned to stay in LEO. It seems like there has been a decline, and the slide does not show that NASA has turned around. The slide is more about learning than doing. *Dr. Olson* said that NASA is laying in a lot of capabilities to do more than the Agency has ever done. But that has to be affordable and sustainable. There is a lot of subsystem work going on with AES, and there are budget constraints. *Mr. Kohrs* said that NASA needs other hardware to go to L1 and L2, and it will take more than 5 years to develop. *Dr. Olson* replied that there are some ISS capabilities. *Mr. Kohrs* noted that there is no chance NASA can do these things by 2017. *Dr. Olson* answered that that is the phase the Agency is targeting, to launch an uncrewed vehicle in that period to do a high-level fly-around or a short flight to L2.

- Referring to Slide 10, which outlines the steps for the various destinations, *Mr. Bejmuk* said that the costs should be added to each step, because that would help shape NASA's thinking. *Dr. Olson* said that it would be premature to assign costs at this stage. *Mr. Bejmuk* replied that no other nation will put forth the resources for dreams. NASA must show why this is important, along with a pragmatic plan.

Status of the Budget for the Human Exploration and Operations Mission Directorate

Ms. Toni Mumford, Director of the HEOMD Resource Management Office (RMO), provided an overview of the budget. The President requested $7.946 billion for HEOMD in FY13, which will meet external commitments, forward development of systems and capabilities required for human exploration of space beyond LEO, support the commercial space industry, and help keep the ISS viable. The plan is to continue ISS through at least 2020. A new division was established in FY12, the Space Life and Physical Sciences Research and Applications Division (SLPSRA). HEOMD also created the GSDO program office to manage the 21st Century Space Launch Complex (21st CSLC) and Exploration Ground Systems (EGS). In addition, the budget supports LSP, purchase of another TDRS, safety initiatives, and the ongoing Space Shuttle Transition and Retirement.

Challenges include the Iran, North Korea, and Syria Nonproliferation Act (INKSNA), which could have a negative impact on ISS operations after 2016. This must be addressed in the FY13 timeframe in order to allow Soyuz purchases at least through 2017, when the commercial crew program should be operating. It is crucial to know when commercial crew operations will be online for the ISS. Demonstrations for commercial cargo are scheduled for this year. The pension estimate on transitioning the Space Shuttle will help determine whether NASA must defer any work. There have been some TDRS failures in Space

Flight and Support (SFS), where NASA is certifying the new LV and working with SMD on making it affordable. HEOMD is also working to mitigate the risk to astronauts of visual impairment and increased intracranial pressure during lengthy space flights. Finally, the Directorate is implementing Rocket Propulsion Testing (RPT) right-sizing study recommendations.

The FY13 budget is close to the FY12 level, which is about as good as can be expected under the current budget environment, though an increase would be better. HEOMD uses the money it is given, with only $37 million left unobligated from FY11 and FY12. There is concern about the decrease for Exploration Systems Development (ESD), but the FY13 request is consistent with the FY12 request. In FY12, however, Congress gave the project additional funds beyond the request, which helped NASA meet milestones.

Regarding the flat budget for commercial crew in the out years, Ms. Mumford emphasized that those budgets are notional, and NASA will work on the run-out over the summer. For hardware other than the MPCV and SLS, this budget gets NASA to 2017. The Agency cannot anticipate wedges in this budget and is looking for international contributions. Aside from an increase in SCaN, the rest of the FY13 budget is flat. The SLS allocation through 2017 is $1.88 billion, including ground systems. The Space Technology Program has moved to the Office of the Chief Technologist (OCT), which has a budget of about $550 million for space technology.

The President's budget request does not extend beyond 2017, which is why there are no additional funds shown for Beyond Earth Orbit (BEO) flights. In FY12, ESD plans completion of the cross-program Systems Requirement Review (SRR), making progress with the Orion MPCV Exploration Flight Test 1 (EFT-1) primary test structure and shipping the structure to KSC, ground testing of J2-X, and SLS program level and component element SRR and System Definition Reviews (SDR).

Ms. Mumford briefly reviewed the ESD plans for FY13, which include completing the cross-program SDR, beginning the next phase of Orion heading to a 2014 launch, and completing SLS Product Design Review (PDR). Orion PDR has occurred and is being synchronized with the SLS PDR. Ms. Mumford also showed the ESD integrated manifest and briefly reviewed the current integrated summary schedule, which was to be discussed in more detail later in the meeting. For the Commercial Crew Program, NASA will complete SAAs in the summer, though some will go into FY13. There are some concerns about the schedules for this program being delayed.

Commercial Orbital Transportation Services (COTS) has SpaceX as having completed several demonstration and infrastructure milestones. The 2+ demonstration mission is scheduled for no earlier than April 30. Orbital has its maiden test flight scheduled for no earlier than June 2012 and will conduct a system demonstration mission readiness review in the third quarter of FY12. The Human Research Program (HRP) will conduct 10 to 15 biomedical flight experiments in FY13 to understand the significant effects of long-duration spaceflight on the human body. The visual problems remain a priority issue and were on the agenda later in the meeting.

AES plans for FY12 involve as many as 500 Full-Time Equivalents (FTEs), as the work is highly labor-intensive. NASA hopes to use the ISS for more exploration research, using the Japanese Aerospace Agency (JAXA) H-II Transfer Vehicle (HTV) and ATV from the international partners. SpaceX cargo vehicle will berth to the ISS and stay up 7 days. The ATV launch was slightly delayed. As mentioned earlier, the Space Shuttle pension settlement later in 2012 could be higher than expected, so NASA has slowed some of the transition activities. The current 2012 plan is to disposition three shuttle orbiters, and Atlantis will move to a KSC visitors' center display in 2013.

SCaN has completion of Key Decision Point B (KDP-B) for the Space Network Ground Segment Sustainment (SGSS) PDR scheduled for June 2012, and continues work on the Lunar Laser Communication Demonstrator (LLCD) and Lunar Atmospheric and Dust Environment Explorer (LADEE). The Division will also complete the PDR for the Deep-Space Station-35 antenna. For FY13, SCaN hopes to complete TDRS-K for a December 2012 launch readiness date, continue progress on TDRS-L, and complete the CDR for TDRS-M.

LSP had five missions in 6 months last year, and has planned four launches in FY12 and three in FY13. In addition, the Program is doing a lot of pre-launch work and providing substantial advisory support to LADEE, EFT-1, Commercial Resupply Services (CRS), and Commercial Crew. The RPT has done a right-sizing study as part of the effort to maximize resources across agencies and commercial test programs, and has a plan to mothball certain test stands in order to eventually bring them back up. Budget cuts have been an issue with the Department of Defense (DOD) dialogues in this area.

NASA is negotiating with the European Space Agency (ESA) regarding the Plum Brook station. Astronaut training is in the budget for HSFO, and this includes looking at the visual impairment issues. The 21st CSLC upgrades and modifications scheduled for FY12 and FY13 should be useful for those using the complex multiple times. This is mostly infrastructure and replacements.

Discussion

- *Mr. Bejmuk* expressed concern about the continued ability of the Russians to participate in the ISS if INKSNA stands. *Ms. Mumford* explained that they will be able to participate in their part of ISS. However, there are a lot of shared resources, and INKSNA prevents NASA from buying needed services from them. NASA is trying to get relief from this.

- Regarding the integrated summary schedule, *Mr. Bejmuk* observed that it allows GSDO to lead the flight hardware design, which is not a good way to operate. *Mr. Cuzzupoli* added that ground operations usually hold up the vehicle. For example, Orbital has a vehicle ready now, but not the ground portion.

- *Mr. Bejmuk* asked about the reserve budget that can be kept at PDR. *Ms. Mumford* said that it varies by project. Orion has more schedule reserves than budget, while SLS is the reverse.

Exploration Planning, Partnerships, and Prioritization Summary

Dr. Olson returned to discuss planning in more detail. HEOMD was asked to examine all DRMs to see if they are synchronized and make sense, to determine how to use the SLS and MPCV to achieve the most goals in the near term; what ISS international collaboration is possible; and how to best support LEO activities in near term.

Life science risk areas for trips to an asteroid and Mars include radiation mitigation, understanding the effects of living in extended periods of lower pressure, and the psychology of isolation. There are DRMs for each of the destination areas that create an envelope for Level 1 program, with the goal of evolving toward some of the more specific mid-term plans. Mr. Bolden specifically assigned Mr. John Shannon the task to look at these near term plans and advise on the best path forward. For operations, deep space navigation and free space docking are key. With system design, there are issues with life support, venting, and thermal control in deep space. Propulsion is being looked at, especially advanced in space propulsion. The limit of 21 days for the MPCV with a crew of 4 is due to consumables, specifically water and oxygen.

The waypoint study team will provide a detailed assessment of cis-lunar activities and look at the early configurations of SLS and Orion. NASA hopes to extend its capabilities to build a longer or stronger platform to help increase duration with a relatively quick return to Earth. L2 and L1 are fairly dynamic missions. The study team is looking at what can be done with existing hardware to support affordability efforts. The cornerstone of exploration is the ISS – its research and technology applications, and its demonstration test bed capabilities. HEOMD is expanding NASA's capabilities and experience with life support, space assembly, and the like.

Dr. Olson showed a lengthy list of current, planned, or proposed ISS technology demonstrations. NASA is trying to make smart choices. The various international communities involved in ISS have good collaboration and cooperation, including for long-range mission scenarios. The ISECG Global Exploration Roadmap includes two pathways in a common strategy to get to Mars. The Russians have a similar strategy. These efforts are yielding strong diversity of inputs and consensus building.

There are two significant ISECG products: the Reference Architecture For Human Lunar Exploration, and the Global Exploration Roadmap (GER). These are nonbinding and facilitate the sharing of ideas. It will be necessary to extend ISS to 2020 in order to solidify support. Dr. Olson presented a comprehensive chart on Iteration 1 of the GER, showing the participants and their activities. The over-arching goal is to build from ISS to Mars. For 2012, the focus is on using ISS, sharing Agency priorities, and defining human space exploration knowledge gaps for each destination. Regarding redundancy and obsolescence in the DRMs, they are now current, including the international ones, which are linking structurally and through products. This enriches NASA's work.

NASA must clearly communicate the benefits of travel beyond LEO to the Agency's stakeholders. Dr. Olson showed an illustration of the building blocks for capability-driven human space exploration. The Human Spaceflight Architecture Team (HAT) completed four different cycles for 2011. The U.S. Office of Management and Budget (OMB) has seen and approved NASA's detailed schematic for a capability-driven roadmap and destinations.

In the area of technology development assessment, the DRMs and element data lead to one-pagers and a summary sheet, which goes to costing and phasing. At that point, the cost risk is rated. Not all numbers are equally known in terms of confidence level. Subject matter experts provide a reality check, creating a lot of fidelity. Dr. Olson said that he will bring a detailed DRM to the next HEOC meeting, with the cost and schedule included.

There are 14 technology areas within the space technology roadmap. These areas are used for assessment and entries. There are many activities in a systematic linkage. DRMs and Technology Readiness Levels (TRLs) are not yet available online, though Dr. Olson would like to have them online. Forward work issues and concerns include cryo-propulsion, initial cryo-stage (interim), off-the-shelf products, whether the moon mission enables other missions, and the leveraging of other missions. In looking toward future, the work toward multiple destinations is tightly aligned with international partners and academia. NASA is trying to build the multi-destination foundation with workers and students.

Discussion

- *Mr. Cuzzupoli* asked about where NASA was going with propulsion. *Dr. Olson* said that the Agency is looking at solar electric, ion propulsion, and strategies for advanced in-space propulsion that includes nuclear thermal propulsion. The Agency plans to conduct a workshop with RSA, but it has been delayed. *Mr. Cuzzupoli* expressed concern about NASA losing its experienced people in this area and asked if Pratt Whitney or others are working on this. He had

been told that the effort was strictly ISS technology. *Dr. Olson* confirmed that it was ISS technology, though there is an advanced booster technology. NASA is looking at polar volatiles and other consumables as part of a broad tapestry of work.

- *Dr. Condon* said that he liked what he heard and understood the approach. However, he was concerned about who knows about it and how the Agency is communicating to the public about NASA's intentions and plans. The public needs to know why NASA is relevant today. Trying to inspire the next generation is good, but that needs the context of the whole nation being inspired by what NASA is all about. He did not think NASA was doing this well. *Dr. Olson* said that he has taken on some of that, trying to communicate clear messages. There are plans to have the website feed information. There are also radio talk shows and reports, as well as a social media presence. NASA is trying to use tweets to drive people to its website, and trying concept maps to allow users to drill down. The Agency is trying to build key talking points with the international community, and shaping the common messages for both the public and the knowledgeable community of employees and experts. *Dr. Condon* noted that a person has to already be interested in NASA for those to be effective. He wanted to know how the Agency is exciting people who are not already interested, and getting beyond the "space geeks." *Dr. Olson* explained that Mr. Bolden does press conferences and college speeches. In addition, there is a science and technology expo on the U.S. mall, and HEO information trailers that are sent to various events. NASA has four digital TV stations, multiple websites, and apps, and is criticized for advertising too much. Still, he agreed that Dr. Condon had a valid point. *Dr. Condon* said that the Shuttle missions got attention. He feels if a public survey would show that the average person does not know what NASA is doing. *Dr. Olson* agreed. He said he would do a briefing on this for the next meeting.

- *Mr. Kohrs* asked why NASA was considering L2 versus the moon for missions. *Dr. Olson* said that the Agency can do a lunar swing-by that assists in getting into L2. The robotic spacecraft are doing it in a kidney-shaped cis-lunar orbit. There are interesting plans that are evolving, so it is premature to write in or out the capabilities.

Status of Space Launch System (SLS), Orion Multi-Purpose Crew Vehicle (MPCV), and Ground System Development and Operations (GSDO)

Mr. William Hill, Deputy Associate Administrator for Exploration Systems Development (ESD) Division, presented an update on the SLS, Orion MPCV and GSDO. Mr. Hill introduced representatives of two ESD projects of note. Dr. Charles Smith, the Chief Engineer for Cross-program Systems Integration (CSI), is on detail from NASA Ames, and Mr. Steve Clarke is the Acting Deputy Director for Programmatic and Strategic Integration (PSI), on detail from KSC.

In the area of system configuration, the Orion MPCV was announced in May 2011, and the SLS was announced in September 2011. NASA completed an independent cost assessment in August 2011 and is working to implement the findings. The cost assessment team was from Booz Allen Hamilton, and included some Washington-based analysts, plus one from St. Louis and two from Houston. The formulation authorization documents have been signed, and a cross-program SRR occurred in November, resulting in 44 Requests for Information (RFIs). A standing review board is in place, and while it does not yet involve contractors, that is being negotiated for the next step.

Current ESD focus is on the SLS, MPCV, and GSDO programs. ESD, a division within HEOMD, manages the three loosely coupled programs. The centers want their own contractors, and ESD runs the three programs in parallel with its own contractors. The Division approves integrated risks and schedules at Headquarters, where it controls the work done in the programs and adjudicates differences of opinion. The contracts take a mix of forms. ESD does all the external communication with Congress and the Office of Science and Technology Policy (OSTP) so that the programs can focus on their activities. CSI manages the technical authorities and provides the chief engineers for the three programs. There are probably 8 to 10 people involved in this at Headquarters, with around 70 total within NASA. Impending restrictions on travel could create problems for this group. Mr. Dumbacher is in charge of managing unresolved inter-project issues, and there is an intermediary board that the three program managers chair.

Ms. Mumford has the RMO resources for ESD, working closely with PSI. There is a Project Planning and Control (PP&C) integration team with seven working groups. Headquarters does the integration work, which is Levels 1 and 2, while the Marshall Space Flight Center (MSFC), JSC, and KSC are Level 3, with some Level 2 people. There are about 30 people at Headquarters and 30 to 40 at the centers. NASA hopes to maintain this system, which the Agency had for Apollo and Challenger.

The proposed ESD budget for FY13 is $2,769,000,000 and stays flat from FY14 through FY17 in a notional budget. By the end of FY13, NASA will have finalized cross-program requirements, though the goal is to accomplish that earlier. The Construction of Facilities (CoF) budget line has about $144 million and prioritizes work on existing contracts. One of the biggest challenges is the Michoud Assembly Facility, which is being augmented out of reserves at Headquarters. NASA is also working with a MSFC contractor that is trying to bring in other tenants. The Agency is staying with Michoud for development of the core and upper stages. NASA wants to maintain the same system for the test article and SLS if possible. The loads will be different. Lockheed Martin is managing and operating the approach with EFT-1, along with spacecraft processing and fueling.

KSC has a flat budget of about $400 million to modify launch complex 39 to support the 2017 launch. The differences between Block I and Block II in the SLS are mostly in the service module. For the crewed system in 2021 – or, ideally, 2019 – the flight will have most but not all of the service module. The subsystems are different and NASA is working on the weight. The budget line for Orion remains flat at about $900 million.

As mentioned, Lockheed Martin is in charge of EFT-1, is strictly responsible for it, is buying Delta 4, and will own the vehicle. NASA wants the flight performance data as part of a contract adjustment. On the MPCV, NASA initiated final Command Module (CM) barrel machining, completed drogue chute wind tunnel testing and Phase 1 water drop testing, and conducted a drop test of the Orion crew vehicle's parachutes. Mr. Hill showed examples of the evolvable configurations of the SLS, from 70 metric tons to 130 metric tons. Differences include advanced boosters between 70mt and 105 mt, and the 70 mt does not have an upper stage. Mr. Hill said that NASA anticipates perhaps four instances where it will need the 130 mt vehicle. Otherwise, it probably does not require that much lift capability early on. Plans are for the Delta IV to be used in the 2014 test flight and the 70 mt SLS will be used for the 2017 uncrewed mission, and the 2021 crewed mission. The 105 mt vehicle will be used for a 2023 mission. The others are not yet designated.

For SLS, NASA was to do a J2X power pack test the next day. The Agency has completed an eight-tests initial campaign of the J2X. There is a core stage, with solid boosters and in the Liquid Oxygen/Liquid Hydrogen engines for the first stage, and NASA is negotiating upper stage activities. A key for Level 3 is having the right people, and ESD does frequent re-evaluations. For GSDO, the 39B is similar to what would have been used for Constellation. NASA is looking at some horizontal launch capabilities and at vertically and horizontally adapted platforms, which might be options with the commercial programs.

These are all under GSDO. Work is being done on the Vehicle Assembly Building (VAB) designs and the crawler transporters. Some of the generators on the latter were up to 40 years old and are being replaced. NASA just put out an RFP for the technical and operations support contractor for launch support. This contract should be awarded in October, with the awardee active by January. Tank and water tower refurbishments are underway.

The core is being designed to carry thrust load from the forward attach points. For the prelaunch test program, the plan now is to test the complete stack, but this has not yet been defined. NASA considered doing this at KSC, and NASA is leaning toward a full upstage firing, firing the full core vertically. The intent is to do it on every stage, but Mr. Hill was not sure that it can be sustained; this too is under evaluation. One challenge of a full Main Propulsion Test Article (MPTA) approach is that if it went to the John C. Stennis Space Center, it would be up to $400 million just for the test stand. If we did a full-up core stage prelaunch test at SSC, we believe it would be $100-150 million less. Either test, the full-up core stage or MPTA would be full duration.

The altitude abort test will be at about 5,000 feet; with command module extraction using the Launch Abort System. Exploration Mission-1 (EM-1) is a BEO uncrewed, assured-return trajectory flight around the moon and back. The SLS LV will have four engines, and the mission will go out and back in about 7 days. EM-2 will be crewed for a 14-day mission that will go into high orbit around or near the moon for 3 or 4 days. The purpose of the crewed mission is to demonstrate the human interface and controls.

Affordability is the new mantra. NASA is trying to accelerate decision-making, manage program requirements and contractor interfaces, and maintain competition and improve acquisitions. To accelerate decision-making, the Agency is trying to leverage lessons learned from previous development programs. Another effort involves flattening the organizational structure by removing a layer. Focus has been on clear delegation of authority and accountability.

The level of reserves is about 5-15 percent on SLS, and 8-10 percent on Orion. Orion has minimal reserves in the first 3 years, then a full year set aside down the road. Lastyear, ESD did a rough top-down budget that was submitted to OMB. This year, ESD is doing a bottom-up look that will be passed up to Mr. Gerstenmaier. There is not the luxury of carrying big reserves, although there is a descope plan that could allow that. In order to prevent losing them, NASA has started calling reserves “unallocated funds.” ESD is holding tight on the schedule.

The ESD integration model encourages decisions at the program level, and the Division is encouraging decisions at the lowest levels possible. Efficient integration leads to spending a lot less money with fewer FTEs and contracts. Mr. Hill has compared accomplishments to plans and suggested that he will be able to make a list available to HEOC in the future.

Affordability is a key element in all ESD actions, although the proposed 20-25 percent reduction in travel will be a challenge. Other elements of affordability include streamlining and minimizing key driving requirements, such as issuing only 21 Level 1 requirements, minimizing the number government staff performing insight and oversight duties, and connecting the risk approach to the use of reserves. The 21 Level 1 requirements run to about 6 pages; Mr. Hill said that he would provide them to the Committee. Two NASA documents address ESD requirements, as opposed to the 85 documents involved in Constellation. ESD is focused on maintaining competition and improving acquisitions. This involves conducting “Will Cost” and “Should Cost” reviews in which NASA has sought outside advice from such sources as the DOD Price Fighters. ESD is also implementing contract incentives for cost reductions, though there will not be that many incentive-based contracts.

ESD is implementing an evolvable development approach, along with robust designs and margins, as part of its effort to leverage existing capabilities. Mr. Hill noted that the Division is allowing contractors to use equivalent Type 1 Data Requirement Documents. He provided some examples of demonstrated cost reduction initiatives, such as partnering with suppliers to analyze cost drivers and possible efficiencies and an incremental approach to building and testing vehicle capabilities. Part of managing contractor overruns is defining requirements. Among many affordability efforts, ESD is leveraging existing Shuttle, ISS, and Constellation assets where practical, infusing operability into design, reducing infrastructure footprint, making greater use of civil servants for management and integration, and enabling flexibility in acquisition. Finally, ESD is looking at better decision-making and program requirement management.

Discussion

- *Mr. Cuzzupoli* asked if NASA had or planned to engage any contractors that contract directly to L2 integration. *Mr. Hill* explained that NASA is waiting to see how it evolves. *Mr. Dumbacher* is responsible for the overall schedule. *Mr. Cuzzupoli* asked if hardware changes and other elements will come through L2 to Mr. Dumbacher; *Mr. Hill* said that they would if they affect the costs or schedule. All the L1 and L2 requirements come out of this group. *Mr. Hill* thought that all the centers were working to this now and working well. There are weekly teleconferences. *Mr. Clarke* will provide a schedule.

- *Mr. Cuzzupoli* asked *Mr. Hill* for a list of all the upcoming products, documents, specifications, and drawings.

- *Mr. Cuzzupoli* thought that the Reaction Control system (RCS) engines are high compared to those on previous projects. He thought it was quite different, and wondered about the placement of the RCS engines. *Mr. Smith* explained that the heat shield has a version of the coating used previously and is a basic Shuttle tile, which is reusable.

- *Mr. Bejmuk* said that if they are using the same launch escape tower as for Aries 1, it is overkill. *Mr. Hill* said that the ratio between the CM and escape tower on Apollo are close in weight.

- *Mr. Bejmuk* observed that the picture of the generic booster makes it look like the vehicle rests on the boosters. If NASA ever goes to liquids, it will require greater diameters, messing up the ground systems and necessitating a redesign. *Mr. Hill* explained that NASA is not trying to preclude using liquids, and may have to support the core and boosters if that happens, or do something different. *Mr. Cuzzupoli* thought they could fix these things. He found the discussion of four versus five engines interesting. *Mr. Hill* said that each design offers a one-engine-out capability, which three engines do not.

- *Mr. Cuzzupoli* asked that, at the next meeting, *Mr. Hill* show the total test program for the complete stack. *Mr. Hill* agreed and took this as an action item. *Mr. Cuzzupoli* observed that thermal vac is not a cheap test, but that the questions have to be brought up. *Mr. Bejmuk* added that on Constellation, it was difficult to comprehend. They were doing an acoustic test and needed a chamber with a high decibel level. *Mr. Hill* explained that NASA will do this with Orion on the Ascent-Abort 2 (AA2). He showed a drawing of what is envisioned for the Exploration Flight Test 1 and explained how the test will operate. *Mr. Smith* added that there will be acoustic load testing. He will check on acoustic test objectives as an action item. There will be thermal couples on the heat shield. This test comes in at slightly less than Apollo.

- *Mr. Cuzzupoli* asked why NASA is returning to the moon, given that the United States has been there and it has risks. *Dr. Condon* agreed that the rationale was unclear. *Mr. Hill* said that the goal is to get out of LEO, but not much more.

- *Mr. Kohrs* asked about the master verification plan at Mr. Dumbacher's level. *Mr. Hill* replied that that is being worked on.

- *Mr. Cuzzupoli* observed that understanding requirements clearly makes for affordability. Once something can be interpreted different ways, cost control becomes an issue. He recommended discussing affordability face-to-face with the contractor. *Mr. Hill* said that that is close to what has happened with Orion, where much work was done to reduce moves and hand-offs. *Mr. Cuzzupoli* said that they must agree on how the hours and rate for a task, and be smart enough to challenge the contractors on the time something takes.

- *Mr. Kohrs* said that Apollo was done with thousands of contractors, and NASA may need to hire some of them. *Mr. Cuzzupoli* asked to see the test plan and master verification plan, with all the tests on a schedule. *Mr. Hill* said that some programs are concerned about becoming a big monolith. *Mr. Cuzzupoli* stressed the need to work out details.

Adjourn

The meeting adjourned for the day at 3:40 p.m.

March 7

Convene Meeting

Dr. Siegel called the meeting to order at 8:30 a.m.

Exploration Technology Development

Mr. Andre Sylvester, Program Executive for Exploration Technology Development (ETD) in the OCT, explained that the Agency seeks to pursue breakthrough technologies that are critical and require technology investments. These will benefit the U.S. economy and span all NASA mission areas. Mr. Sylvester began by showing a list of the components in the ETD portfolio, noting which elements had synergy with AES. He explained that in-space propulsion is mostly non-chemical. The focus is on advanced lithium ion batteries, regenerative fuel cells, photovoltaic arrays, and the accompanying outcomes. The regenerative fuel cells will help reduce the number of consumables. NASA does not want power to be a limiting factor, and an increase in battery capability will help this effort. Photovoltaic is expensive, though the Agency is working to bring down those costs. In conjunction with the U.S. Air Force (USAF), NASA is looking at large flexible solar structures. Along with the Defense Advanced Research Projects Agency (DARPA), USAF has developed fast arrays. At this point, the TRL is not what NASA wants, but collaboration continues toward creating these structures. NASA has focused on developing large flexible substrate solar array structures to TRL 5 in order to support crewed Near Earth Orbit (NEO) missions over the long term. The Agency also hopes to demonstrate the long-term durability of inflatable structures. Inflatable structures usually use straps or some other material to restrain objects, so there is a need to understand those materials and their performance. There are not many contracts in this area, and the ones that exist are primarily in-house and at NASA centers.

Another goal is to design and build robots for exploration systems. Mr. Sylvester reviewed some of the successful tests and prototypes in this area. He explained that human-shaped robots are designed specifically to assist humans and use existing tools employed by astronauts. It is often easier for the humans to interact with the human-shaped robots. Many other robots are not shaped like humans, and some burn lots of fuel and are very hot.

Next Generation Life Support (NGLS) is being worked on at a number of centers, with the goal of developing key technologies for Extravehicular Activity (EVA) Portable Life Support Systems (PLSS). The objectives include reduction of hardware mass and elimination of EVA duration limits for EVA Carbon Dioxide (CO2) removal hardware, increased EVA pressure settings, and recovery of almost all exploration waste water.

In the area of autonomous systems, where NASA Ames is the lead, OCT is developing software technology to support operation of habitats and cryogenic loading. For In-Situ Resource Utilization (ISRU), NASA is trying to develop instruments that can detect ice and volatile elements on planetary surfaces. Two instruments are in development – a neuron spectrometer and gas chromatograph/mass spectrum analyzer – and a near infrared (NIR) spectrometer is being designed. OCT sees its purpose as infusing technologies like these into missions.

The NRC report highlighted advanced radiation analysis tools. For these, NASA hopes to develop the ability to forecast solar radiation events and learn to assess radiation effects on space structures. At this point, much of the analysis is disjointed. OCT wants to improve the Solar Energetic Proton (SEP)

warning system to inform risk mitigation steps. These are ground tools, not space-based. If the radiation analysis allows NASA to build a lighter structure, that will be a big help.

Mr. Sylvester next talked about in-space propulsion, where the goal is leveraging investments made by the Air Force Research Lab (AFRL). These include a 13kW Hall thruster and a 160-200V power processing unit. NASA is trying to mature the thruster to TRL 6. OCT typically tries to take technology from TRL 3 to TRL 5 or 6, at which point a mission group seeks to test it so that Mr. Gerstenmaier will be willing to fund it. The power source on the thrusters consists of solar arrays. NASA is making progress toward a non-chemical, non-nuclear solution, and some of the new solar array technologies could support a Mars exploration activity. However, time and the number of thrusters are issues. It might be that the solar array would be used to power cargo, not crew.

Solar electric propulsion is an area of technology development. An active project at the Glenn Research Center should soon produce mid-term reports to focus further work. OCT is able to bring multiple groups together to realize objectives efficiently. In looking down the road at outer solar system exploration, the feeling is that higher power will be needed. NASA is looking now at a non-nuclear demonstration of fission power subsystem-level readiness. Between nuclear and solar, NASA is spending about $15 million. There is no single clear choice in the solar area.

Another big area for OCT is Composite Cryogenic Technologies and Demonstration (CCTD), where the goals are to advance the technologies at diameters suitable for future heavy lift vehicles, and identify spin-off capabilities. There is a significant weight issue with the heavy lift vehicles. Out-of-autoclave manufacturing is a big advance, where OCT is building two different sizes of tanks. One of the desired outcomes is a 30 percent weight savings and 25 percent cost savings. This is being led at MSFC. In the area of Hypersonic Inflatable Aerodynamic Decelerators (HIAD), Mr. Sylvester explained that if humans are to go to the outer planets, they will need a larger structure to slow them down as they get there. This is an attempt to demonstrate performance in heat environments. NASA is pursuing ways to test representative sizes outside of putting the objects into orbit, though a May demonstration launch will send up a 5-meter relevant scale structure.

The deployable aeroshell concepts and conformable Thermal Protection System (TPS) is mostly a science area right now. NASA discovered that the Agency had lost the ability to build some of the TPS products it used in the 1960s, and is now trying to regain that ability. One goal is to build bigger pieces so that there are fewer of them requiring less effort to put together. NASA has found ways to reduce their heat load on re-entry. The Autonomous Landing and Hazard Avoidance Technology (ALHAT) was moved to OCT. It involves an integrated hardware system with a high degree of capability. OCT is now working on a vertical test bed. It does not fit the Orion schedule, but looks way beyond it. The goal in Cryogenic Propellant Storage and Transfer is to mature technologies and support long-term in-space storage. Mr. Sylvester quickly reviewed the Mars Science Lab and Entry Descent and Landing Instrumentation (MEDLI) and Materials International Space Station Experiment (MISSE-X). Regarding avionics, NASA is looking at multi-core technologies studies in the spring, and wants to kick off an avionics project in 2013.

Discussion

- *Mr. Cuzzupoli* stressed that reusability should be a goal with cryogenics, solar arrays, fuel cells, and batteries. It will save costs. He asked why it was not in the presentation. *Mr. Sylvester* said that longer life is the current focus, especially on fuel cells, where it reduces some of the operational challenges. It is a way of addressing a similar goal. *Mr. Sieck* suggested thermal protection as an area where that could be done. If something lasts long, reuse is not part of the

picture. *Mr. Sylvester* gave an example of a technology meant to be used multiple times a day for 5 to 10 years.

- *Dr. Longnecker* was struck by things that can interact with HRP and the National Space Biomedical Research Institute (NSBRI). The human-shaped robots, for example, reflect the interaction of people with robots. In the area of radiation detection, NSBRI has contracts out to develop detectors for flight. For ISRU, they discussed how science could interact with the biomedical side. There is a host of such things. He asked about the relationship between OCT and HRP and NSBRI. *Mr. Sylvester* said that OCT is doing increased technology development across the Agency and outside, coordinating the function. JSC is in charge of this project for NASA and has been passing along information. *Dr. Longnecker* said that he has seen both strong interactions and major gaps in this area. He is concerned about both duplicative work and lost opportunities. *Mr. Sylvester* said that this is being addressed at the Agency level.

Advanced Exploration Systems

Dr. Christopher Moore, Acting Director for Advanced Exploration Systems (AES), explained that AES is trying to build capabilities that will take us beyond Earth, using the NASA workforce to maintain competencies and gain hands-on ability. Objectives include advanced development of exploration systems; demonstrating prototype systems; pioneering innovative approaches; infusing new technologies into exploration missions; and pursuing robotic precursor activities. AES is also working closely with SMD. The long-range activities of OCT feed into ETD and AES, which in turn contribute to HAT. While OCT focuses on the long term, AES integrates into prototypes, following a capabilities-driven approach. The Program focuses on four key capabilities: deep space habitation, crew mobility, crew-centered operations, and robotic precursors.

Dr. Moore presented a timeline of 20 small projects from the four key capabilities. Projects each last around 3 years. In 2013, AES will integrate these into larger efforts. An example is a crew excursion vehicle under the crew mobility capability. The results of AES efforts are products and tests. The Program tries to move these out quickly. There are a number of innovative approaches to affordable new capabilities. AES projects follow a "skunkworks-like" model for rapid development of prototype systems. The Program maintains critical competencies at NASA centers and provides NASA personnel with opportunities to learn new skills and gain hands-on experience. AES works with ESA, the Canadian Space Agency (CSA), and the Department of Energy (DOE), while also trying to engage the public through NASA's Center of Excellence for Collaborative Innovation (COECI).

The centers are responsible for development of the crew systems. Dr. Moore did not know how high the 2014 launch will go, but it is highly elliptical and deep. When NASA goes to Mars, there will be a need for very high energy propulsion systems. NASA is working on that with DOE and testing at MSFC. Dr. Moore reviewed the vehicle systems under development at the centers, as well as the operations projects. To help contractors work to reduce the costs of operations, AES is involving them as part of the project teams, but most of the work is being done in-house. As ideas mature, AES will hand off some of them, and is trying to involve contractors early. AES will not impact Orion or SLS, as the Program develops next generation systems to explore BEO.

Robotic precursor activities include imaging near-Earth asteroids, prospecting for lunar ice, measuring the Mars surface radiation environment, and joint robotic precursor activities. Dr. Moore reviewed recent accomplishments of AES, such as the crew test of the Multi-Mission Space Exploration Vehicle (MMSEV), the NASA Extreme Environment Mission Operations-15 (NEEMO-15) underwater test

conducted in November, the Radiation Assessment Detector (RAD) also tested in November, and the Goldstone Radar project.

Discussion

- *Mr. Bejmuk* pointed out that the Space Shuttle was designed for performance and safety, with little attention to operations. He wondered if operations can be incorporated better into new designs, observing that some technologies required a person with six arms. This had to be included in design and cannot wait until the end. Contractors must have incentives to address this. *Mr. Mark Uhran* of NASA said that that was one of the reasons for merging Operations and Human Exploration. *Dr. Moore* gave the MMSEV as an example. It was tested with astronauts in the desert, and the astronauts found it difficult to work with, so it has evolved further. AES does this testing to make technology both affordable and operable. *Mr. Kohrs* asked if some of the technology development was transferred when the organizations were combined. *Dr. Moore* said that some went to OCT last year. The budget does not make clear that workforce costs are embedded at full costs. Therefore, it is important to remember that procurements are lower than the budget lines. AES involves civil servants to the extent possible.

- *Mr. Cuzzupoli* asked who could show him the list of technology improvements that will be on SLS and Orion. *Dr. Moore* said that ESD has that. He added that AES just transferred three projects to SLS. *Mr. Cuzzupoli* cautioned that NASA has to identify that. Someone will ask where the money went if improvements are not obvious or explained. *Mr. Uhran* said that Mr. Dumbacher can answer that question. Many of the improvements reduce costs of operations. *Mr. Sylvester* said that this is an OCT issue, and the Office is very sensitive to that.

International Space Station (ISS) Operations and Utilization Plans

Mr. Uhran, Director of the ISS Division in HEOMD, proposed that, in future meetings, he spend about 15 minutes on an update before going onto an in-depth special topic, as ISS is hitting a rhythm. He presented a list of recent highlights on Systems and Vehicle Operations and Maintenance (O&M). He noted that ISS has completed 14 debris avoidance maneuvers, and debris avoidance panels will be up on the Soyuz by the end of the year. He added that SpaceX is due to go up on April 30 for its first demonstration flight to ISS.

ISS has a Program Risk Advisory Board (PRAB) that meets monthly to triage risks that have been introduced for mitigation, along with new risks. Anyone can introduce a risk. A current challenge is the pressure to reduce costs. ISS operations cost is around $1.5 billion per year. It used to be about $3 billion per year, so this is an area of ongoing work and success.

Another risk is that of clinically defined visual impairment/intracranial pressure, observed in seven astronauts so far. NASA is focusing on developing countermeasures. A research and clinical advisory panel has been recruited and has met once so far. It looks like the problem is not permanent, but that has to be ensured. The Journal of Nutrition just released an article hypothesizing that the issue is nutrition-related. Though it has been said that only males over 40 suffer from the problem, correlations are still being determined. It could be due to a polymorphism that causes some individuals to react while others do not. NASA has seen it in 20 percent of its crew and is concerned. RSA says that it has not observed it, but that agency is extremely interested in NASA's work.

The ISS Program continues to work anomalies that are to be expected in any complex system. The Direct Current Switching Unit (DCSU) is an example. However, there are adequate spares on board for most cases and logistics capacity is sufficient to resupply spares when necessary.

There have been articles in the journal Nature, one on the JAXA Monitor of All-sky X-ray Image (MAXI) data combined with NASA Swift data to record the first observation of a relativistic x-ray burst from a supermassive black hole destroying a star. There have also been articles on self-ordering systems and on biofilm formation.
Finally, ISS went to a lot of trouble to standardize payload racks, lockers and drawers so that apparatus could be easily relocated, and now a private firm, NANOracks, LLC is taking standardization to the next level so that standard nanocubes can be easily integrated.

Mr. Uhran walked through the tactical flight plan, showing the flight crews, the EVAs, docking ports, traffic, and launch schedules. The Memorandum of Understanding with Russia has half of the six astronauts being Russian, and half from other nations. The agreements with Europe, Japan, and Canada are used to determine the mix for non-Russian crew assignments. ISS operates with enough margin that the recent Soyuz failure during processing allowed the flight to slip without major impacts. Commercial cargo should soon become a reality as well with demonstration missions scheduled over next several months.

The 30S is the first Soyuz with enhanced Micrometeoroid and Orbital Debris (MMOD) protection. NASA is trying to determine what, if any, ATV support will be provided in the latter half of the decade. This is a very important period as the ISS International Partners seek collaboration for the future.. The standards for the ATV and HTV flights are being applied to SpaceX and Orbital as well. The objectives for SpaceX flights 2 and 3 may be combined if all the objectives of flight 2 can be met on schedule and with sufficient remaining margins to pursue the flight 3 objectives. The ISS Mission Management Team (IMMT) will be meeting during the mission to make go/no-go decisions

Mr. Uhran showed a graph of desired versus actual and projected weekly crew time for Increments 29 and 30. This was in catch-up mode but has now recovered. Another figure showed progress with critical spares on the last two Space Shuttle flights. This effort has been very successful, resulting in a good number of spares. No one sees a high threat in this area, but there is some risk in the commercial vehicles being delayed. The Soyuz has been extraordinarily successful, which is why the risk is not high.

The international partners met last month in Quebec City and produced documents on ISS utilization statistics and ISS benefits to humanity. ISS is currently authorized through 2020, and there are no identified barriers to go beyond that, but a lot depends on operating experience and the value. There has to be a benefit/cost tradeoff. The team is looking at 2028. The direct cost to NASA of building the ISS, in an audited version, was $51.7 billion through the end of FY 2011, including the Shuttle missions. This does not include partner investments, which exceed $10 billion.

ISS Robotics Capabilities and Demonstrations

Mr. Ronald Ticker, Space Station Manager for Development, presented an overview of ISS robotics research, technology development, and future concepts, focusing on the Mobile Servicing System, the Kibo External Facility, and the European Robotic Arm. The arms are used in berthing. In the area of research and technology demonstrations, the Robotic Component Verification on the ISS (ROKVISS) is a joint Russian/German project that demonstrates lightweight robotic systems. Robonaut2 is human-shaped robot to demonstrate humanoid robot capabilities to assist astronauts. This is funded by General Motors (GM) and NASA through OCT. The success criteria involve the ability to mimic humans and do what a human does. These robots can augment the crew for normal operations. Since crew time is a limitation,

this creates a benefit in relieving crew. The Robonaut2 can pick up very small items and hold very heavy things. GM is interested because the device mimics human dexterity and could go into an assembly line where there is a need for fine skills. It has no voice or legs, but it can "tweet."

The Synchronous Position Hold Engage Reorient Experimental Satellites (SPHERES) are three bowling ball-sized free-flying satellites operating inside the ISS to study multi-body formation flying within the hull. Algorithms for formation flying are being developed through these ISS experients. ISS SPHERE Integrated Research Experiments (InSPIRE) builds on SPHERES. Zero robotics is part of InSPIRE, a competition for high school students to build robotics. They develop code that can be uploaded to SPHERES in orbit. The finals were conducted on ISS interactively with the crew. SPHERE Slosh is an OCT-funded demonstration of fluid behavior in microgravity.

The Robotic Refueling Mission (RRM), launched on the final Shuttle flight, is a joint NASA/CSA effort that just began operating. It uses CSA's Special Purpose Dexterous Manipulator (SPDM), called Dextre, with Goddard Space Flight Center (GSFC)-developed tools and task boards, which are designed to replicate on-board systems on orbit. RRM is meant to show how robots can re-fuel, service, make minor repairs to free-flying spacecraft. There are a lot of legacy spacecraft up there now. Other experiments have shown how to service systems, but most satellites were not designed to be serviced. NASA is trying to change future satellite design philosophy, but needs a demo to show designers that it is possible. Mr. Ticker showed images of four RRM tools and discussed how Dextre will use them in summer 2012.

Future concepts include building a large aperture optical structure for future telescopes. Tool development for satellite servicing is being done at GSFC, with optics being done at the Johnson Space Center and Jet Propulsion Laboratory (JPL). Another concept study, from InSPIRE, is to take SPHERES to assist astronauts on EVA. The vision for future human/robotic collaboration includes enabling of large construction projects, which can be explored more through the use of Dextre. ISS robotics are providing a testbed for future space science exploration and robotic development.

Status of Commercial Crew/Cargo

Mr. Philip McAlister, Director of Commercial Spaceflight Development, explained the latest activities with commercial cargo and crew. The program had a good number in the proposed FY13 budget. The COTS demo flights have not yet launched. Orbital is doing well on cargo flight preparations, but is having problems with the launch pad readiness, which has been a bigger issue than they expected. They now expect to launch no earlier than June, and Mr. McAlister expects the launch to occur in mid- to late summer. Orbital will test the Antares launch vehicle with a mass simulator payload which will go to orbit.

The issue with pad readiness is partially due to a lack of clarity about who is responsible among Orbital, the Mid-Atlantic Regional Space Board (MARS), the NASA Wallops Flight Facility (Wallops), and COTS. Most of the responsibility falls to MARS, some of it is Orbital's issue, and there are disagreements sometimes as to who pays. Mr. McAlister sees it as primarily an integration issue. There was some lack of detail in the initial planning. Operations should be more distinctly Orbital's responsibility. There will be a test firing on the pad before the company launches. In terms of the missed schedule, NASA is finding ways to make equitable adjustments and has worked out some innovative ways of moving forward, since everyone wants this done. Through COTS, NASA pays for milestones and does not pay the companies extra when they take longer or redo tests. At this point, NASA does not know when the pad will be ready, but the handover from MARS to Orbital is expected in April.

SpaceX is looking good and did a successful wet dress rehearsal the previous week. The April 30 launch date looks good so far, but there is still a lot of work to do. The schedule is not the driver here; ISS is well supplied this year. However, NASA wants to get some additional cargo up soon. For the test launch,

there is low-value cargo on board, such as clothes and water. There is an approved plan to combine Flights 2 and 3 into Flight 2+, but the decision will be made in real time, once the spacecraft is on orbit. Flight 3 is the berthing. If SpaceX does all but berth, it could possibly go to a CRS mission. NASA does not pay until the company meets its mission objectives. This is not a make-or-break test flight, however. If it succeeds, NASA will still have to pay attention to future flights, and if it fails, SpaceX will need to determine root cause and implement a fix and we can move on. The greatest concern is the expectations of external stakeholders, and NASA is still planning some communications to address that.

Mr. McAlister described the activities of the four funded partners under CCDev2. These four companies are all trying to be the safest, most reliable, most cost-effective way of getting Americans into space. All are very different, and all are trying to satisfying the requirements in different ways. Blue Origin is about halfway through its milestones, as is Sierra Nevada Corporation (SNC), which delivered a mock-up of its Dream Chaser test article. Boeing just completed a PDR that has yet to be approved, and will have a drop test later in March in the desert. SpaceX just had astronauts interact in its capsule. The three unfunded partners – ULA, ATK, and EAI – receive no funding from NASA but do get limited technical assistance and a review of their designs. ULA is based on making the Atlas 5 human rated. Most unfunded work is with boosters.

The objective of the Commercial Crew Program is to facilitate development of a U.S. commercial human space transportation system that can achieve safe, reliable, and cost-effective access to LEO and the ISS. The Program sought $850 million in FY12 but received $406 million, and was told to review its acquisition strategy, which was done. The Program expects to have a crew transportation system in place by 2017, if not sooner. SpaceX and Orbital proposed the COTS original schedule. Thus, NASA took some precautionary measures and there was indeed some slip.

NASA has extended the period for doing design work under the SAA and plans to use that contracting vehicle for a while. It should be more cost efficient and prevent having to renegotiating contracts. SAAs are more flexible and can accommodate NASA's uncertain budget levels. The providers have more responsibility and make more decisions. However, they still have to meet NASA's requirements in order to be certified to fly NASA personnel. There will be no reduction in safety requirements or expectations.

Mr. McAlister showed the timeline for the Commercial Crew Program and explained that delaying the transition to Federal Acquisition Regulation (FAR) -based contracts will prevent NASA from mandating compliance with certification during the next phase of SAAs. NASA's strategy to address this includes having more than one company in the next phase of SAAs, making the Agency's requirements available to all providers for reference, and structuring certification to allow the Agency to fully evaluate the technical progress of the providers.

Discussion

- *Mr. Cuzzupoli* observed that the launch pad situation at Wallops will involve a test on the pad, ultimately adding more than a week of activity. The issue is that it is not clear who is in charge. Orbital's biggest mistake was in not learning who is in charge. *Mr. Sieck* agreed, saying that it is hard to understand why this happened. *Mr. McAlister* said that it is mostly an integration issue. The roles and responsibilities issue has not created a delay, but the situation has created uncertainty. There have also been technical issues.

- Regarding the SpaceX test Flight 2+, *Mr. Cuzzupoli* said that NASA's reputation is on the line regardless of what happens. NASA is in the new situation of having no responsibility for making the booster perform correctly. This puts NASA at the mercy of the contractor, because if the booster fails, NASA will be blamed. *Mr. McAlister* agreed, noting that NASA would have to share responsibility based on participation, and there will be a failure at some point.

- *Mr. Cuzzupoli* said that he never sees anything in writing about the relationship between NASA and the contractors, such as when NASA takes over control. *Mr. Uhran* said that NASA's responsibility is at the keep-out zone, and the Federal Aviation Administration (FAA) is responsible for launch and entry. *Mr. McAlister* added that there is a document outlining responsibilities, plus a detailed mishap plan. *Dr. Condon* observed that while the contractors have responsibilities, NASA is the steward of the taxpayer dollars provided for this purpose, so NASA will always be viewed as responsible. That is a legitimate point of view. Regarding the budget issues, NASA will not succeed by saying that a failure could cost more.

- After seeing the timeline, *Mr. Cuzzupoli* made two observations: 1. He noted that NASA has not dropped the language about fixed price contracts. This Committee recommended against fixed price contracts. He wanted that on the table, as HEOC still disagrees with fixed price. 2. Commercial Space received a budget of $400 million despite seeking $800 million. He asked if NASA had considered having fewer contractors in order to get more done for the $400 million. It will take a lot to fly by 2017, and the budget still might not be enough. *Mr. McAlister* explained that the three slots for contractors shown under the Commercial Crew Integrated Capability (CCiCap) section of the timeline were notional. There will be more than one contractor, but the exact number has not been set. That will be funded in FY12 and FY13, and the proposed budget for FY13 is about $800 million. The Program is not specifying the number of companies at this point. As for changing the time of the NASA certification, that would be costly. Partner integration teams are reviewing the work, and NASA has significant insight into their activities. However, NASA does not have the ability to tell the contractors what to do with their designs. This is a development process, but it does not push the technological state of the art.

- *Mr. Cuzzupoli* said that mistakes are made in building new vehicles, and there is a lot to learn. *Mr. Richard Malow*, participating by phone, added that he worries about the FY12 budget cycle, because commercial space did not do well. He wondered if the program would survive should it not receive the $800 million. *Mr. McAlister* replied that it would survive, though the timing could slip due to the need to replan. That may involve an earlier reduction in the number of competitors. *Mr. Malow* advised Mr. McAlister to consider that. *Mr. McAlister* added that every added year is another $500 million to the Russians. As soon as Commercial Crew comes on line, that money stays here and gets the United States back flying to ISS, which is at risk if anything happens to Soyuz. Orion is by law a back-up to commercial crew, but it would be expensive to use as a regular ISS crew transportation system.

- *Dr. Condon* noted that without the funding, there are only a couple of choices: sacrifice competition for the schedule, or slip the schedule. *Mr. McAlister* could not say which is more important. Dr. Condon saw the schedule as a driving force. *Mr. McAlister* explained that a reduction in competition might not affect the schedule. The contractors are working hard. He sees the competition as possibly being less expensive than going with a single contractor. *Dr. Condon* clarified that he was not advocating a single contractor, but questioned whether carrying more than two might affect the schedule. *Mr. McAlister* repeated that he did not know. *Mr. Malow* suggested that he was being careful about answering. *Mr. McAlister* said that it has to be more than one, and two might sound good. The question would arise should one drop out, in which case NASA would have only one contractor. The Agency does not know which companies will be there at the end. All four are doing well now, and NASA does not know where they will go.

- *Mr. Kohrs* asked if NASA looks at the contractor business plans. *Mr. McAlister* replied that yes, NASA scrutinizes them. *Mr. Bejmuk* asked if, under SAA, NASA can incentivize contractors based on the schedule. *Mr. McAlister* explained that NASA uses milestones. There is a fixed

amount of money that the contractors get earlier or later. They cannot receive more than what is negotiated. *Mr. Bejmuk* described how it was done on the Space Shuttle. Every paragraph was certified to. *Mr. McAlister* said that NASA will do commercial crew the same way. There are baseline requirements that the contractor must meet to sell to NASA. For certification, the contractors must prove they have met those requirements for the visiting vehicle and elements. The requirements address performance rather than spelling out how to accomplish the activities.

- *Mr. Cuzzupoli* emphasized that HEOC wants NASA to succeed. In history, each center had its background and knowledge. Human space flight was at Johnson, launch was at Kennedy, etc. It bothers him that on commercial crew, KSC, the launch people, are responsible for the vehicle. It is possible to transfer people, but he wondered why NASA was not using Johnson's experience, with thousands of workers who have done this before. *Mr. McAlister* said that NASA is on this. The percentage is not even, but it is close. *Mr. Cuzzupoli* said that this bothers him.

Deliberations and Discussion

Mr. Kohrs said that he thought the presentations were well done, especially the AES presentation. He suggested that the Committee review the recommendations from the previous meeting. He began with the recommendation about fixed price contracts.

The proposed recommendation was: "HEOC recommends that NASA modify the proposed fixed price Integrated Design Contract to a more conventional contract mechanism such as cost plus incentive fee."

Mr. Kohrs asked if HEOC wanted to keep this in light of what they had learned. Dr. Condon suggested that while HEOC still holds the position to avoid fixed price, they heard that fixed price contracts are not being issued. The consensus was to hold this recommendation for the time being.

Another proposed recommendation was to define a destination. Dr. Condon wanted to keep that one, but asked that they add that HEOC understands the financial constraints on the Administrator. He thought that Mr. Gerstenmaier has laid out a good approach under the circumstances. Going forward with the recommendation might be excessive, and he suggested writing another recommendation that makes some of the same points. Mr. Kohrs noted that, in regard to forming an international group to lead exploration, the relationships are being set up. His frustration is in wanting NASA to do more. There is constant talk and a lack of urgency to the cooperation; the international group is meeting in December to talk more. This is happening at a high level, but the group only meets once a year. There should be more emphasis on completing agreements. Mr. Sieck added that without more focused effort on a destination, the development work is just a jobs program with no goal. Unless there are agreements and timetables, it is just so much churning.

Dr. Condon said that it is unlikely NASA can do all this without international cooperation. His concern was how to get Americans excited about NASA again. Telling young people that NASA will build a big rocket that it might use is not inspiring. Mr. Sieck agreed. Mr. Cuzzupoli added that before NASA inspires the public, it must invigorate its own employees, who are demoralized. Dr. Condon agreed, saying that HEOC has made that point with the Administrator. For 50 years, the Administrator and people within NASA have known their destination, and now they do not. This recommendation could reignite the fire in the Administration and public. Mr. Cuzzupoli added that once the State Department agrees with another country to go beyond LEO to a destination, it is hard to backtrack because there is a commitment.

Dr. Longnecker observed that when the Committee pushed back with Dr. Olson the day before, he said that Mars is the destination. If so, there must be a change in how this is presented. HEOMD presents the incremental steps to Mars instead of presenting a destination with incremental steps. They should feature

the goal and use it to build excitement and interest. Dr. Condon agreed, noting that there were crewed flights beyond LEO 40 years ago. NASA needs a clear end objective and an understanding of why it is important. Mr. Uhran said that working with the partners is a slow process. He thinks the partners will concur on the next steps. The United States and Russia are the prime partners. Dr. Condon added that this is also a NAC recommendation to the Administrator.

There was discussion about wording of the recommendation, whether to specify Mars, state that NASA is working on the building blocks to Mars, or specify a "near term" destination such as the moon. Dr. Condon recommended wording for the rationale, to state: "pick a specific destination, such as Mars. In addition, the near- and interim steps in order to achieve the ultimate objective should also be defined." HEOC should be clear in recommending that NASA be clearer. The Agency should reunite the workforce and re-ignite the excitement of the American public.

In reviewing the "consequences of no action" section of the recommendation, the Committee agreed that while it is important to acknowledge what NASA can do with the constrained budget, the Agency cannot get more funding without a plan. If NASA only works on capabilities, it will go nowhere. Mr. Kohrs said that one of the reasons the current budget is flat-lined is because there is no plan. He noted that the previous NAC picked over the wording of this type of recommendation, but Dr. Squyres has indicated that he will lead in this direction.

Dr. Condon noted that, related to the draft recommendation addressing EM-2, it is important to develop specific mission objectives to justify the need for a crewed lunar orbit mission. NASA should show that the Agency can do more than was done with Apollo and show that the objectives are consistent with the cost and risk involved. NASA is open to public criticism and loss of Congressional support if the Agency cannot justify the need for conducting a mission such as EM-2. Mr. Kohrs noted that EM-1, the uncrewed mission, is needed because it provides re-entry velocity and tests the new heat shield. While it is an important delivery milestone, it has to have a purpose. HEOC decided to support the draft from the previous meeting.

Dr. Longnecker wanted to examine some of the issues related to the physical sciences and life sciences, which need to come together in integrated way. Dr. Longnecker said that he would write a draft recommendation endorsing such a subcommittee and urging Mr. Gerstenmaier to move forward with it.

The next suggestion for a new recommendation addressed the structure of international partnerships. The concept was that NASA should leverage the existing partnerships to continue expanding international participation in future exploration. The analogy was that the United Nations (UN) has many nations, but functions effectively because it has the Security Council. NASA should have a group equivalent to the Security Council. Mr. Kohrs said that HEOC wants to see more urgency to the whole process. As the recommendation was drafted, it was noted that NASA should accelerate expansion, instead of continuing. It was noted that although HEOMD does not have partners for exploration beyond the ISS, SMD has many international partnerships. The concept of "acceleration" is key. International partners need something to follow, and the lack of specific plans has stalled these partnerships. Among the "consequences of no action" are that limited U.S. resources will delay exploration of the solar system.

Mr. Sieck said that HEOC should find out from Mr. Sylvester how much is being spent. If NASA wants to go beyond LEO, the Agency needs to look harder at propulsion technology, beyond $15 million per year. That just upgrades existing technology and is a meager amount. Mr. Cuzzupoli suggested that HEOC find out what the international partners might have done in this area and determine what they can contribute. Mr. Sieck explained that he had no recommendation, but he wanted to note that this does not sound right, especially in light of NASA's goals. Mr. Kohrs added that NASA has concluded that a trip to Mars is not likely without a non-chemical means, which points in the direction of nuclear or solar.

After discussing the pros and cons of a potential recommendation on strengthening inter-program integration, it was agreed to hold it until the next meeting on the grounds that HEOC had asked NASA staff to come back with more information, and they should have an opportunity to do so. Another point to be held for the next meeting was the situation at Wallops. Mr. Kohrs said that he would bring this up at the NAC meeting if no one else did.

Comments from the Public

HEOC held a public comment session. There were no comments from the public.

Adjournment

The meeting adjourned at 2:42 p.m.

Appendix A - Agenda

Tuesday, March 6, 2012

8:30–8:35 **Welcome & Call to Order**
- Mr. Richard Kohrs & Dr. Bette Siegel

8:35–9:05 **Status of the Human Exploration & Operations Mission Directorate**
- Mr. William H. Gerstenmaier

9:05–10:35 **Capability Driven Roadmap**
- Dr. John Olson

10:05–11:05 **Status of the Budget for Human Exploration and Operations Mission Directorate**
- Ms. Toni Mumford

11:05-11:20 **BREAK**

11:20–12:20 **Exploration Planning, Partnerships, and Prioritization Summary**
- Dr. John Olson

12:20–1:30 **LUNCH**

1:30–2:30 **Status of Space Launch System and Multi-Purpose Crew Vehicle**
- Mr. William Hill

2:30–3:30 **Ground System Development and Operations**
- Mr. William Hill

3:30 **ADJOURN**

Wednesday, March 7, 2012

8:30–8:35 **Welcome & Call to Order**
- Mr. Richard Kohrs & Dr. Bette Siegel

8:35–9:45 **Exploration Technology Development**
- Mr. Andre Sylvester

Advanced Exploration Systems
- Dr. Christopher Moore

9:45–11:00 International Space Station (ISS) Operations and Utilization Plans

- Mr. Mark Uhran

ISS Robotics Capabilities and Demonstrations

- Mr. Ronald Ticker

11:00-11:10 BREAK

11:10–12:10 Status of Commercial Crew/Cargo

- Mr. Phil McAlister

12:10–1:10 LUNCH

1:10-2:15 Deliberations and Discussion

2:15-2:30 Comments from the Public

2:30 ADJOURN