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

NASA Headquarters, Washington, DC

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Table of Contents

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Status of the Human Exploration & Operations Mission Directorate – Joint Session with the NASA Advisory Committee (NAC) Science Committee

Mr. William H. Gerstenmaier, Associate Administrator for NASA's Human Exploration and Operations Mission Directorate (HEOMD), provided an overview of Directorate activities—framed by opening comments surrounding the current budget environment within NASA and HEOMD.

The President's budget request for Fiscal Year (FY) 2014 provides $7.798 billion for HEOMD to lead and manage human spaceflight in and beyond low earth orbit (LEO) with a long-term goal of a human Mars mission in the 2030s. The guiding principle of the budget is to use the International Space Station (ISS) to the fullest extent possible. HEOMD is expected to continue developing the human capabilities required to explore beyond LEO, while NASA continues partnering with industry to develop commercial crew capabilities. The commercial cargo capabilities are progressing well toward the goal of delivering services and materials to ISS on a regular basis. HEOMD is also expected to provide safe and reliable access to space for NASA and NASA-sponsored payloads, as well as deliver space communications and navigation services to customer missions. Finally, HEOMD is to support its research arm, which aims at providing advanced research and technology for mission systems required to reach beyond LEO. This area of work includes an asteroid redirect mission to the lunar vicinity in the early 2020s.

Mr. Gerstenmaier next reviewed additional details within the FY14 budget, pointing out that the projected budgets for FY15 through FY18 are notional. The budget is essentially flat, which requires additional efficiency every year in order to maintain the same level of program effort while absorbing inflation.

Programs

Mr. Gerstenmaier reviewed the progress and milestones of individual programs. The Orion spacecraft continues to progress towards its initial test flight aboard a Delta IV Heavy, scheduled for 2014. With the test flight, NASA hopes to quantify the actual flight performance metrics and possibly remove additional mass. Other major systems, such as the inert abort motor, the launch abort system, and the heat shield, are in various stages of design and development. This process is providing NASA and contractor personnel with a great deal of assembly experience.

The Space Launch System (SLS) went through wind tunnel testing, as well as design cycle analysis and review. Mr. Gerstenmaier described some of the specific testing and construction. A tremendous amount of work has been done to move forward toward a heavy launch vehicle, with hardware getting ready to fly for the 2017 test flight. The actual launch date of 2017 is closer than it seems, and the team must keep moving and focus on this major milestone. At NASA's Stennis Space Center (SSC), the team is conducting a "green run" test build-up for validation purposes.

At Kennedy Space Center (KSC), there is a great deal of activity in the Ground Systems Development and Operations (GSDO) program, using basic infrastructure, often with some modifications to accommodate the new launch systems. At the Wallops Flight Facility, Orbital Science's Antares A-One rocket was set to launch in order to test stages, although it had been rescheduled due to a rigging/connector issue. Orbital's Cygnus spacecraft was also at Wallops, and preparations were being made for a June test flight. In parallel, the Lunar Atmosphere and Dust Environment Explorer (LADEE) is planned to launch from Wallops later this summer.

Commercial Space

Mr. Gerstenmaier showed the timeline for the commercial crew transportation system development. Certification requirements were given to the contractors – the Phase 1 contract allows them to recommend changes for NASA's approval, while Phase 2 will be the certification contract(s). Phase 1 is small but critical, ensuring that industry and NASA agree that the requirements are right.

ISS Research

Scientific research and technology development are becoming increasingly important for ISS, which has become an orbiting microgravity laboratory. Ongoing research encompasses five primary areas:

- Biology and biotechnology;
- Earth and space science;
- Human research;
- Physical research; and,
- Technology testing and development for future human spaceflight systems.

Expeditions 35/36 will include 140 investigations, 82 of which will be NASA/U.S.-led, and 58 of which will be international -- these activities will represent more than 400 investigators around the world. Mr. Gerstenmaier gave some examples of Earth science experiments. Crew time spent on research now exceeds 35 hours per week at times, with a recent week getting up to 38 hours. NASA recently upgraded the ISS-mission control communications system from two lines to four, which will greatly improve science throughput and maximize researchers productivity.

Initial results have come in from the Alpha Magnetic Spectrometer (AMS), an ISS-based device that looks for dark matter by examining the ratio of positrons to electrons. AMS provided tremendously detailed data. The mission has determined that there is no unique source of positrons; it is not definite whether or not these are pulsars, however. There are about one million data points that all have to be processed and confirmed by the research teams, two of which have independently looked at and validated the data to date.

Asteroid Strategy

NASA's asteroid strategy aligns NASA science, space technology, and human exploration capabilities into one activity. The Science Mission Directorate (SMD) has an existing asteroid identification and characterization effort related to planetary defense; now NASA will look for smaller objects as well. In addition, the Agency hopes to advance Solar Electric Propulsion (SEP) by leveraging use of this system in transport to and from the target asteroid. HEOMD's robotic servicing activities and its SLS and Multi-Purpose Crew Vehicle (MPCV) initiatives towards asteroid rendezvous are also folded into this effort. The benefits from this joint use of capabilities accrue to future exploration objectives for carrying humans farther into space.

The asteroid mission would consist of three main segments: identify, redirect, and explore. The target asteroid will need to already be on a trajectory heading toward the Earth or lunar vicinity in order for the SEP to redirect it to a lunar distant retrograde orbit. To accomplish this, the Agency will need to find an

existing object of the right size, compositional characteristics, spin rate, and orbit in order to capture and redirect the asteroid. NASA's ability to find such an object is under review for possible improvements within the systems. unknown, though it could be that the target ends up being a spent piece of space hardware.

The number of known Near-Earth Asteroids (NEAs) has grown tremendously in recent years, along with the ability to detect increasingly smaller NEAs. The problem with small objects is that they are fleeting, swift, and hard to see. There may be only a dozen or so that meet this mission's criteria of a small asteroid that is 5 to 10 meters across. The plan is to design and build the robotic spacecraft to cover a range of targets and then build in more specificity about a year before the target comes into range. NASA might not be able to capture the object. If that happens, the SEP capabilities are still demonstrated. But care must be taken in setting expectations, since there is no guarantee that this will happen.

The target object will be in an orbit similar to that of Earth. The burn arcs on the electric propulsion will go for about one year, truly testing this capability. To assist the teams in designing the launch systems, the asteroid 2009 BD was used as the "target" asteroid, although the actual selection will likely be different. Using 2009 BD, the trajectory from launch to capture is 671 days, and retrieval will be another 1092 days. NASA has developed a video simulation of an asteroid capture. The capture device must be "soft" enough to capture the asteroid slowly without overloading the solar array, and it will have to ride with the asteroid for a while before redirecting it over several years to reach the desired lunar orbit. NASA did simulations to look at the variable spin rate and mass in order to begin understanding what is needed to go forward in the design of the mission and spacecraft systems.

Based on our observations to date, the smaller the asteroid, the faster it is able to spin. Some of the smaller ones appear to resemble "rubble piles" – a loose gathering of rocky and frozen gaseous debris. This is part of the challenge for asteroid observation and characterization, and another reason there is no guarantee of a capture. Another challenge is that of helping the public to understand that the asteroid will be small enough that it is not going to cause harm if the redirect attempt results in an entry into Earth's atmosphere.

In describing the Earth/moon system trajectory, Mr. Gerstenmaier explained the orbit trim maneuvers required for long-term stability. The capture device will do arcs around the moon and Earth to get the gravity assist required to create the spin leading to an orbit around the moon. Between the Earth's and the moon's gravity, the device and captured asteroid will remain stable between the two bodies. Mr. Gerstenmaier noted that, for purposes of discussion, his graphics used a specific object (2009 BD) for proof of concept. This is not the target object, just part of the initial feasibility study.

In a 22-day nominal Asteroid Redirect and Utilization Mission (ARUM) overview in which NASA uses Orion with an Extra-Vehicular Activity (EVA) capability, NASA expects to have two EVA opportunities. The Agency is working on the feasibility of this concept, which was an exercise to determine what changes, if any, would be needed on the Orion spacecraft. This mission would take humans farther from Earth than ever before, creating the need for crew to operate autonomously. In case of an emergency aboard the ISS, astronauts could be brought home within hours; but in the current ARUM concept, opportunities to abort the mission and return to Earth could be 9 to 11 days away at any given time – a very different risk posture that will require different capabilities. More work is needed on this.

The asteroid mission capabilities support NASA's long-term Mars strategy. The mission will provide a necessary demonstration of the core capabilities required for deep space missions. These include advancing SEP, robotic activities, and deep space navigation and communication, orbital maneuvering, along with human operations beyond LEO. The initiative will also further NASA's ability to work and interact with a small planetary body.

Mr. Gerstenmaier noted that the asteroid initiative fits well in context of NASA's strategic principles for the incremental building of capabilities. There will not be a huge budget for this, so it will require use of high Technology Readiness Level (TRL) systems and near-term capabilities. Once the redirected asteroid is in a lunar orbit, it will remain there for up to hundreds of years, allowing long-term use for commercial interests, multi-use space infrastructure, and international participation.

Summary

In summarizing his presentation, Mr. Gerstenmaier said that the budget allows HEOMD to continue progress on its existing activities. While tight, the budget is workable. The asteroid redirect mission offers a strategy to link several planned activities into asteroid redirection, and points the way to an integrated approach to the long-term goal of Mars exploration.

Discussion

- *Ms. Nancy Budden* asked about the relative difference in complexity between going to the moon and capturing an asteroid. *Mr. Gerstenmaier* explained that there is no lander cost associated with the asteroid mission, which can use Orion and SLS as they were designed. The asteroid capture can also be accomplished in a single launch. Lunar equipment will be much more expensive and complex. *Mr. Bohdan Bejmuk* asked how this mission might be coupled with the concept of planetary defense. *Mr. Gerstenmaier* replied that this will provide more experience with asteroids and lead to a wider range of approaches.

- *Dr. Wesley T. Huntress, Jr.,* Chair of the NAC Science Committee observed that while the discussion has focused on the technical challenges, this may be a management challenge as well. The retrieval vehicle will rely on very specific launch times, beyond what is currently done in HEOMD. *Mr. Gerstenmaier* said that the Mars Rover teams in SMD have this type of experience, which the mission will draw upon. There will also need to be work on shielding astronauts in the case of a sun event, requiring additional effort in the area of cosmic radiation as well. The mission will seek the input of the planetary science community, starting with the mission feasibility review to be conducted during the summer. *Dr. Huntress* noted that SMD will be augmenting its ground-based detection capabilities, and *Dr. Janet Luhmann*, Chair of the Planetary Science Subcommittee (PSS), said that the Small Bodies Analysis Group (SBAG) that reports to PSS is very interested in this effort.

- *Dr. Stephen Condon* explained that in terms of this mission supporting the long-term Mars strategy, one could say that it is an integral step toward Mars, or that it is a step that could determine whether or not we do go to Mars. He asked if the asteroid initiative is part of the process leading to human exploration of Mars, or a single effort. *Mr. Gerstenmaier* said that it is a step, part of the capabilities piece. This mission starts meeting some of the key objectives and filling in knowledge gaps.

- *Mr. Richard Malow* asked how much time would be needed from Orion. *Mr. Gerstenmaier* answered that Orion will keep a 21-day capability for four crew. Orion can serve as an emergency or escape vehicle, and it augments a habitation module. The next generation life support is demonstrated on ISS and the next-stage ISS. For everything going on today, NASA is looking to where it moves forward. The habitat would be for follow-on, not the asteroid capture.

Center for the Advancement of Science in Space/ Status of Research Subcommittee

Dr. D. Marshall Porterfield, Director of the Space Life & Physical Sciences Research & Applications Division within HEOMD, discussed the status of both the Division and the Center for the Advancement of Science in Space (CASIS). The Division was formulated to develop science research that extends human exploration. Its three focus areas are space biology, physical sciences, and human research. Division programs conduct fundamental and applied research to advance basic knowledge to support human exploration in the space environment. The Division is also NASA's liaison with CASIS, which is the ISS national lab management organization. Dr. Porterfield gave some examples of the Division's research, which encompasses both basic and applied research. Involvement with CASIS allows work on hardware development and other common interests. The Division does not advise CASIS on what research to pursue, however. NASA funds CASIS at $15 million annually. Half of the ISS national lab resources are set aside for CASIS.

The FY11 President's budget gave NASA the specific direction to establish an independent research management organization for the U.S. share of ISS utilization capacity. NASA released a Cooperative Agreement Notice (CAN) in February 2011. Objectives stated within the CAN included identification of the unique capabilities of the ISS that provide breakthrough opportunities for non-NASA use; identification and prioritization of the most promising research pathways; and, increase in the utilization of the ISS while facilitating matching of research pathways with funding sources. CASIS was chosen from among four proposals and was awarded a cooperative agreement in August 2011, to operate through September 2020. The original proposal was developed by Space Florida, which also provided the interim board members.

CASIS is currently looking for an executive director and recently designated the interim chief scientist as the chief scientist. The first research produced by CASIS focused on the life sciences, with a review of the literature from the previous 10 years. The Center also selected three proposals in response to a research announcement on protein crystal growth, which will be on the September 2013 SpaceX launch.

Dr. Porterfield listed the current members of the Board of Directors. The Board tries to identify the CASIS business model and otherwise provides upper-level leadership in determining how to best fulfill the cooperative agreement. While the current Board members tend to be from academia, the NASA perspective is that the Board should also include venture capital or other business expertise. Board members are paid about $30,000 annually, plus expenses.

The Board's current top priority is hiring a permanent executive director. The Board is also developing its strategy and mission concept for CASIS. CASIS has completed two solicitations, selecting proposals in protein crystal growth and materials science. The CASIS Science Advisory Board is currently examining the potential for Earth observation and non-embryonic stem cell culture aboard ISS. The respondents to the solicitations tend to be universities, though Proctor and Gamble is involved in one experiment. There is also interest in studying the use of animal models for osteoporosis and drug discoveries.

HEOC Research Subcommittee

In March, 2012, the NAC recommended the creation of a subcommittee that "…advises NASA on the research and educational needs that are required to support a plan for the long-range human exploration of space. The subcommittee should include a breadth of perspectives that encompass research and higher educational needs, not representation of specific disciplines." The Research Subcommittee chair is Dr. David Longnecker, an HEOC member. The first subcommittee meeting occurred on April 17, 2013. It covered the ethics review, an overview of the program, focus, and early stage plans for moving forward.

Discussion

- *Dr. Condon* asked if the Subcommittee had consciously excluded anyone with an industry background. *Dr. Porterfield* said that there had not been such a decision, and he thought the Subcommittee had a good balance of disciplines. *Dr. Condon* replied that he was thinking about experience. The Subcommittee had representatives with academic and NASA experience, but no industry research experience. The perspective from someone with an industry background would be very different from the academic perspective. *Dr. Porterfield* said that since it is a research organization, it might skew more to the academic side. *Dr. Longnecker* added that the terms of reference allow the Subcommittee to have eight members, and there were only six at that point. They would consider Dr. Condon's input in filling the other two slots.

- *Dr. Longnecker* continued by noting that one of the exciting things is that the term "fundamental science" has come back into NASA. For a while, the Agency had focused only on applied science. With some of the physical changes occurring to astronauts, NASA needs to go beyond just developing a treadmill for space, and also learn about the basic mechanisms at work. This is a real opportunity, a step in the right direction. *Dr. Porterfield* agreed. NASA has a unique opportunity in the area of personalized medicine, along with study in a controlled environment. His Division is focused on providing researcher access to the space environment, and on ISS utilization. ISS has taken on some of the development costs, leaving the Division more funds for investigation.

- *Dr. Porterfield* also explained how the Division enables access. Instead of following the traditional model of funding a Principal Investigator (PI) for years, with the result being a published paper, the program is using the open source model that has been so successful in SMD. In this model, the science missions measure everything possible, develop bioinformatics tools, put the data into a database, and then fund ground-based investigators to discover what they can from that data. Instead of a single PI, there can be 150 scientists working on a project. The informatics will also be tools for CASIS. This open source science approach can allow dramatic results in a short time. *Dr. Longnecker* said it provides more opportunity to do data-driven hypotheses.

Status of Exploration Systems Development

Mr. Daniel Dumbacher, Deputy Associate Administrator for the Exploration Systems and Development Division (ESD), presented an update on Division activities.

ESD Status and Schedule

Mr. Dumbacher began by reviewing some of the mission accomplishments discussed by Mr. Gerstenmaier at the beginning of the meeting. He also discussed activities at the Michoud Assembly Facility (MAF), where the SLS is ahead of schedule in some areas. SSC will do core stage testing. The decision was made to go to four engines. The analysis indicated that a fifth engine did not add very much, while three engines are not enough. Mass threats and opportunities are tracked monthly and are still above the requirement. Mr. Dumbacher then described some of the GSDO accomplishments. He explained that NASA is focusing on Pad 39B. While 39A is not exactly mothballed, KSC is looking at it, and some external entities also might be interested.

Mr. Dumbacher next reviewed the summary schedule and the schedule for Exploration Flight Test (EFT) 1. Orion is still working toward a 2014 date. The flight test article ready for ground processing will probably slip into February or March, but the flight date is determined by launch vehicle availability, so there is still some margin. NASA will only fly Orion as a flight test on Delta IV Heavy, then only on SLS. Exploration Mission (EM) 2 will be the first crewed launch.

EFT-1 Update
The heat shield for EFT-1 has arrived in Boston, Massachusetts where work has begun on the service module assembly and the structural test for the crew module is being set up. This is a flight test vehicle, not for crew, that will be used for an altitude abort test in 2018. The service module bulkhead work is ongoing, and the project is on schedule.

ESA Service Module
In December, a Memorandum of Understanding (MOU) was signed with the European Space Agency (ESA) for the Exploration Mission 1 (EM-1). NASA is providing an engine and thruster. The service module will include all of the standard functions, which Mr. Dumbacher described. ESA is committed to delivering one service module and parts for a second. There is some work to be done beyond that. There is no plan to take this to SSC for a complete service module test.

Discussion

- *Mr. Richard Kohrs,* HEOC Chair, asked if NASA is providing propellant tanks. *Mr. Dumbacher* said that he thought it was an ESA responsibility, but he would verify that. NASA is providing the separation panels. The key is that NASA retains control of the load paths and the key interfaces, along with the avionics. *Mr. Joseph Cuzzupoli* asked about controllers, which *Mr. Dumbacher* described as key interfaces that NASA will continue to check. The Agency did have the required International Traffic in Arms Regulation (ITAR) documentation in place in order to sign the agreement.

- *Mr. Dumbacher* showed a video of a mock-up of the project, some of which he explained as it played. Modifications were made to the parachute systems under Aries and Constellation, so further modifications are not anticipated. NASA has decided not to recover the boosters; this is a cost-savings measure decided upon after much debate. There are engines for four flight sets. The Agency will use Orion booster data for EFT-1 in order to avoid another huge design cycle. The abort tests will run first, unmanned, and these will be water landings.

- *Ms. Budden* asked if there is a range to which the mission cannot go. *Mr. Dumbacher* said that L1 is harder than L2, since travel to L2 can use a lunar gravity assist. The service module has one engine. *Mr. Kohrs* said that the most reliable engineering NASA has is the service module. *Mr. Dumbacher* replied that NASA will eventually look at different service module engineering, but that is far off.

- *Mr. Kohrs* said that HEOC had sent NASA a recommendation regarding outreach. *Mr. Malow* pointed out that the President's FY14 budget request has taken outreach away from NASA. Based on a General Accounting Office (GAO) report, Education and Public Outreach (E/PO) was moved to three other agencies. This has caused quite an uproar, and Congress will likely look at it carefully. This is not related to sequestration, but is causing a lot of comment.

Status of International Space Station

Mr. Kirk Shireman, Deputy Manager of the ISS Program at Johnson Space Center (JSC), provided an update on program activities. He began by showing a schematic of the flight plan. Most important is the top row across, which shows crews by name, nationality, and when they are scheduled to be on ISS. The stage EVAs are also listed, most of which are for upcoming Russian modules. The schedule also lists EVAs that are pieces of hardware to be replaced on orbit. It is easier to do them back-to-back and have all the spacewalking occur in one time frame. The very bottom of the chart shows the launch schedule. The

gaps between crews indicate when arriving and departing crews do not interact. Otherwise, there are "direct" interactions in which the crews are on ISS at the same time.

Four-Orbit Rendezvous

On March 28, 2013, the 34 Soyuz vehicle did a four-orbit rendezvous for the first time. The time from launch to docking was approximately 6 hours. From a vehicle standpoint, there is little difference between 4 or 34 orbits, but the Soyuz procedures had to change somewhat. With a 34-orbit rendezvous, ISS can be just about anywhere in its orbit. To do four orbits, however, the phase angle is much smaller. This meant that the Station orbit had to be controlled weeks in advance. Overall, this method takes more finesse and planning. Future plans are for a mix of 4- and 34-orbit rendezvous.

To prepare for the four-orbit rendezvous, NASA conducted a flight readiness review on March 6, in which much of the focus was on human factors. The March 28 launch was at 3 a.m., so much focus was given to the sleep shifts of the crew and other workers, ending up with about 14 hours from crew wake-up to docking with ISS. This ties into the issue of Space Adaptation Syndrome, which encompasses a wide spectrum of symptoms. Crew members who have flown before find the symptoms less intense on subsequent space flights. The United States has long used medications to help reduce symptoms, with initial doses given on the ground in order to test for adverse reactions. The Russians tried this, which was new to them. The crew members were in the pressure suits about two hours longer than usual, and had access to the orbital compartment for hygiene, food, and water. They were able to loosen their straps to alleviate joint pain. The ISS team is now conducting a "lessons learned" exercise in preparation for the next four-orbit launch, which could occur on May 30, 2013.

It is hard to say whether the four-orbit rendezvous will become standard, although the Russians seem to want it. The reaction from the flight and engineering crews was positive and, with a few tweaks, the Program should be able to do again. Most of the issues can be controlled. Plans are to have the commander or copilot be a flown crew member, so that there will be advance knowledge of how that person will react to Space Adaptation Syndrome.

Research Program

ISS recently had a Ku communications unit installed, which expands the space-to-ground channels from two to four, and adds video channels as well. The upgrade is working and everyone is pleased with it. For the 35 expedition, the mission objectives include 35 hours per week of crew time for payload investigations. Mr. Shireman reviewed some of the upcoming payloads along with planned vehicle traffic. The crew recently had its longest week doing research. The average has been 37.55 hours per week. There are some slower weeks planned for May and July, when U.S. crew members come home, but the plan is for almost 41 hours per week at end of the 35/36 increment. Out of 140 ISS investigations, 82 are led by NASA and/or U.S. investigators.

Consumables

Mr. Shireman reviewed the status of consumables on ISS. For food, various waste containers and inserts, water, oxygen and LIOH (lithium hydroxide), which removes carbon dioxide, he presented the dates to reach the reserve levels and to reach zero supplies, with both no resupply and with the 51P launch. Each column indicated the shortest resources. There are plenty of resources, but the team watches this continuously.

System Challenges

Each solar array has its own cooler, the Photovoltaic Thermal Control System (PVTCS). These are sealed, but there was a small leak and the leak rate is growing. A spacewalk took place to address this, and the ISS team continues to watch it. The Sequential Shunt Unit (SSU) occasionally produces more power than needed, and sometimes spontaneously reboots. It began doing that quite a bit and then stopped. The team

is monitoring it. The Ku-Band Antenna Group 2 (AG2) had a failure with an external device that will be replaced on spacewalk, at which point ISS will have redundant capability.

Columbus has two water pump assemblies, and one is down right now. The spare will be launched later this summer. The Common Cabin Air Assembly (CCAA) is like an air conditioner and processes water as well. It is not holding the water out of the cabin like it should, so it is being monitored, with the possibility of a replacement at some point. In addition, a freezer shut down due to a false fire alert. The Main Bus Switching Unit (MBSU) is a power feed that allows ISS to power loads if a solar array goes down. It tripped, and the team investigated. It belongs to the United States, but the Russians use it. The investigation indicated that the Russians were creating noise on the system. They have since replaced the box on their side.

Another system challenge was with the Dragon Draco thruster check valve. The last SpaceX flight had propulsion problems just after launch. It turned out to be a check valve problem, which SpaceX managed to correct. In addition, the Japanese Space Agency (JAXA) had an HTV3 abort issue. The HTV (H-II Transfer Vehicle) does a small burn when it leaves ISS, then it does increasingly large burns until it lands in the Pacific. If it is about to harm ISS, it may declare an internal abort. This is what happened, resulting in a larger burn as the HTV3 moved away from ISS. This was considered in the design, but it was still a surprise. The investigation found that the geometry is such that a pin that slides out introduced a small translation rate that caused it to think it would violate an abort line. The team is looking at ways to mitigate that. Mr. Shireman noted that the Dragon geometry will not do this.

Lithium Ion Batteries

The team is building lithium ion batteries for the solar arrays, which the mission will start changing out in 2016. The current batteries in orbit are nickel hydrogen batteries that lost performance while sitting on the ground. Each solar array powers six batteries in Orbital Replacement Units (ORUs), which weigh more than the lithium ion replacements. The lithium ion batteries provide better performance as well. There are design features that prevent a heat chain reaction.

System Enhancements

There have been issues with the carbon dioxide removal assembly, related to a clogging powder venting into ISS. Replacement of legacy ISS avionics continues. The Integrated Communications Unit (ICU) had the biggest impact, so that was handled in order to have activation in early April. It doubles the downlink rate and provides an eight-fold increase in the uplink data rate. There is also now wireless outside of the ISS. The unit is close to off-the-shelf, and was tested as the unit most tolerant of radiation. These are on orbit now, and more will go up soon. Some can be used all over the Station. Mr. Shireman does not believe that the Russians have something to convert U.S. power on their side. NASA has given them some of these units, and he expects that they will either use U.S. equipment or change the plug/adapter. Grounding is very important. The U.S. segment is grounded, while the Russian side has a return wire. NASA made it a condition that they had to ground to our standards before they could use the units.

Status of SpaceX, Orbital, and Other Launches

The second SpaceX cargo flight, SpX-2 (SpaceX-2), was very successful. It safely took up and brought down cold samples, which were distributed to researchers upon landing. The mission also took unpressurized cargo out of Dragon's trunk. Orbital's hot fire test flight was successfully completed in February. The first Orbital flight to ISS is scheduled for late June. The test flight will be a major milestone.

ESA's ATV (Automated Transfer Vehicle) 4 launch has been delayed due to problems with a Digital Signal Processing Unit (DPSU) late in the process. It is now back on track. The last ATV flies roughly one year from now. This does not affect how NASA funds exploration or the Station, all of which are

under HEOMD. ESA wanted to build something new, but NASA was not interested in their proposed new capsule. ESA is now providing the service module for the NASA capsule.

JAXA rescheduled launch of its HTV4 due to a potential Earth Sensor Assembly issue. Orbital has an agreement to use a control panel and other equipment with JAXA, similar to other vehicles by Orbital.

Risk Matrix
The recent risk review board identified the top risks as funding for commercial crew and Soyuz. HEOMD has funds to buy Soyuz flights to 2017, at which point commercial crew should be the transportation of choice. The concern is that NASA does not want to be without a U.S. crew on ISS if the commercial crew program is not ready. An overlap would be expensive, however. NASA will announce soon the number of additional Soyuz flights it has purchased. Other serious issues include pension harmonization and sequestration.

Program Focus
From a tactical standpoint, the Program focus is on maintaining or increasing crew time and resources for utilization. This is the top priority, followed by the budget, ATV, HTV, and integration of commercial crew with ISS.

Strategically, the Program aims to maximize use of ISS as a national lab, working with CASIS in order to use the Station for technology development and technology demonstration for exploration ideas. The crew transportation plan is another area of focus, as is extending the life of ISS. Activity through 2020 is not an issue, but NASA is looking at extending to 2028, which needs to be formalized within about 1 year. The budget remains a concern.

Discussion
- *Mr. Bejmuk* asked for more detail about the risk matrix, noting that Mr. Shireman had said the highest risk is overlap in commercial crew and Soyuz. He could see that as a financial concern or also as concern about the reliability of Soyuz. *Mr. Shireman* said that he was only concerned about the potential gap between commercial crew and Soyuz. He is worried that commercial crew will not be ready and that there will not be U.S. representation on ISS. His team is trying to mitigate that in a number of different ways.

Status of Commercial Spaceflight Development

Mr. Philip McAlister, Director of HEOMD's Commercial Spaceflight Development Division, picked up where Mr. Shireman left off by addressing the overlap issue. NASA is comfortable using Soyuz but will switch to commercial crew as soon as possible. However, Soyuz flights must be bought three years in advance, which calls for making difficult predictions. NASA is working on a strategy for that. The goal is to start commercial crew flights to ISS in 2017. Funding is the primary factor in setting that pace.

The three companies that have Phase 1 certification contracts are Sierra Nevada Corporation, SpaceX, and Boeing. They are all hitting their milestones and some have submitted their deliverables in order to get early feedback. NASA plans to issue Phase 2 certification contracts in the spring or summer of 2014. There are flight tests in Phase 2, but this will be left to the companies.

For Phase 2, NASA would prefer to have more than one contractor if the budget allows. The best posture for the government is in competition, which is not just about price – it is also about safety. The companies are strongly motivated to compete on safety. The Phase 2 certification contract is a very complicated procurement. The Federal Aviation Administration (FAA) is part of this, and there are many details involved. There are no timelines for decisions on the optional milestones. These vehicles are not just

transportation; they also serve as the escape. The providers will determine the number of crew, which NASA has not dictated despite wanting at least four. This should not be a problem, as all three companies are designing with the capacity for seven.

NASA is now determining how well the companies' designs meet NASA safety and performance requirements. The Phase 2 certification contract will be based on Federal Acquisition Regulations (FARs). For most part, NASA is letting the companies decide how they will meet the top level requirements. NASA is also trying to leave the design and development decisions up to them. The Agency has specified what it would provide. While NASA does not want to be in the critical path, it might be necessary to be involved in the docking system and communications. There is also discussion about global crew rescue services using Department of Defense (DoD) assets. When the vehicles are docked, NASA will provide services. The Agency hopes there will be flights without NASA crew. NASA wants industry to own the program, preferably at a fixed price. The customers should be NASA and other entities. NASA will provide investment via milestones. If NASA is the only customer, a cost-plus charge is appropriate.

The Florida-based Booz Allen Hamilton Inc. (Booz Allen) team that worked on the SLS and GSDO did an independent cost analysis (ICA) of the commercial crew program. The purpose was to be sure that NASA has realistic and achievable cost and schedule estimates. Booz Allen determined that although the cost estimates are optimistic, they are also high quality and follow standard best practices. NASA differed slightly on the recommendations regarding cost growth. Mr. McAlister noted that the Agency has reserves to cover some potential cost growth.

NASA has assigned an office of primary responsibility for each finding to develop responses and applicable implementations. The analysis demonstrated that the Agency's underlying assumptions feeding into costs were accurate. Budget cuts could stretch out the program, however, resulting in more cost. Another issue is how much NASA and industry will each pay.

In the FY13 budget, the Division received 20 percent more than in FY12, but that was 40 percent below the request. This could affect the 2017 launch dates, though the providers think they can be ready sooner. NASA will be able to fund the FY13 Commercial Crew Integrated Capability (CCiCap) milestones and complete the early certification activities. If the Program receives $822 million next year, the 2017 launches should be doable. It is increasingly important that the full amount of the budget requests come through.

The tradeoff is between either stretching the date or going to a single contractor. Both the schedule and competition are very important. If this becomes a choice of one over the other, it will depend on the Phase 2 proposals and their quality. There would be a big difference if, for example, one proposal was "the gold standard" versus two companies presenting proposals of similar quality.

Prematurely eliminating competition is a primary risk. The government loses leverage when there is only one supplier, and a single company with no competition has less incentive to invest further. It would be better to have two companies, as with the cargo side.

Discussion

- *Mr. Cuzzupoli* asked about insight verification and the number of people involved. *Mr. McAlister* replied that there are approximately 30 Full-Time Equivalents (FTEs) assigned to each partner in the crew program. These are mostly program office civil service personnel.

- *Mr. James Odom* asked about how the Russians factor into all this. *Mr. McAlister* explained that NASA is just buying a service from them. After the Agency became comfortable with using the

Soyuz, it became a simple services buy, with no cost sharing or anything like that. NASA will be buying commercial services, hoping that it will be cost effective. Ownership will have to be specified. NASA wants the companies to maintain as much intellectual property as possible.

- *Dr. Condon* asked whether, once the development process is complete and NASA is comfortable with the service providers, the Agency will require American flag carriers, or if it is possible that NASA might be amenable to a Russian offer. *Mr. McAlister* said that he expects NASA will be buying from U.S. providers. He cannot rule out a foreign service carrier, but he does not expect it.

- *Ms. Budden* asked whether slipping is really an option if the budget does not improve. *Mr. McAlister* replied that the providers want non-government customers, so continuation of the ISS beyond 2020 is a factor. If the companies are unsure about the non-government market, that becomes a disincentive. The goal is to have a total of two flights per year, total for NASA personnel. That means one each if there are two providers. It is part of the business case.

- *Mr. Odom* said that it could be risky to go to one provider and not have overlap with the Russians. *Mr. McAlister* agreed that there is a need for overlap capability initially. The assumption is that commercial crew will be cost effective compared to the Russians. If the Russians lowered their price, that would become an issue.

- *Mr. Cuzzupoli* noted that the ISS extension is an issue. *Mr. McAlister* said that there are risks to the Station today in terms of meteor hits and other hazards. The companies will use their judgment on this.

Discussion and Recommendations

Mr. Kohrs led the discussion of HEOC findings and recommendations. He noted that NASA had accepted a previous recommendation on outreach, while another one on system integration was not so well taken. At the next meeting, he would like to have a longer, in-depth conversation or video conference with Mr. Dumbacher's group.

Dr. Condon's greatest concern was related to the sequestration. He said that the probability of a grand resolution is slim, with the Democrats and Republicans being at loggerheads in a way that is hard to resolve. Even if there is a solution, it will require a spending reduction similar to this. DoD has advocacy in Congress, so there is some likelihood that there will be efforts to mitigate the impacts of sequestration on DoD in future years. If that is true, it will come from non-defense programs, and NASA is a prime target. NASA has got to either become much more outspoken on the unacceptable impacts or plan what to do with a lot less funding.

Mr. Malow said that it would be hard to compose a recommendation on this. In the FY13 budget process, Senator Barbara Mikulski ensured that NASA did better than some other agencies. Others in Congress were interested in NASA as well. However, there was also the rescission that required cuts across the entire bill. That could happen again in FY14. At that point, NASA starts running out of flexibility, and it could be devastating. The President has proposed a budget that is higher than what sequestration would be in FY14, but that only works if he gets an agreement. Without an agreement, the FY14 budget will go below that for FY13. Meanwhile, DoD has advocates, and there are deals in the works. The law says to cut all agencies equally, but it did not happen that way. Each agency has at least some flexibility.

Dr. Condon suggested that rather than writing a formal recommendation or finding, the members of the NAC should engage with Administrator Bolden, though they do not know what he might be doing behind the scenes. However, NASA should either make its case with the public, or make plans for reduced funds.

Mr. Kohrs said that that conversation between the NAC and the Administrator would occur the following week. He promised to keep the Committee members informed.

Mr. Bejmuk said that NASA is working on things it does not need now, if ever, such as the study for advanced boosters. It is painful. Mr. Kohrs agreed that it is painful, and the schedule will slip, but unless there is a drastic move to shut a facility, it will not change. Dr. Condon pointed out that DoD did not plan for sequestration in FY13 because they did not think it was going to happen, and they did not want it known they were planning to make do with less money. He suspected it was the same at NASA.

Mr. Kohrs noted that another recommendation was that NASA should pick a destination. Now the Agency is talking about visiting an asteroid or Mars. If a flight goes to L2, it will stay there, and the plan with the asteroid will have an orbit in L2. It looks like the whole project is based on solar electric propulsion, which has yet to be developed. He wanted to know more about the activities of the new technology mission directorate, especially since Mr. Gerstenmaier is dependent on their activities.

Ms. Budden said that the asteroid mission is an Administration-specific idea. No one in the science community wants to do it. This means that it will go away at the end of this Administration, at which point there will be a new destination. Mr. Bejmuk said that if the mission were characterized with certain elements that are key to planetary defense, it might have some life and gain support. He would say that a small asteroid will allow the United States to develop planetary defense capabilities. Others agreed that NASA should cast the asteroid mission as a strategy to benefit humans, and Ms. Shannon Bartell pointed out that Mr. Gerstenmaier did not touch on the fact that if we can detect an object better, we can defend against it better, and Mr. Gerstenmaier did not talk about how the asteroid mission helps outside of NASA. Dr. Condon expressed concern about the possible lack of a longer-term objective. This could be a stepping stone if the real objective is a mission to Mars. He considered Mr. Gerstenmaier to have a vision and be very logical, but Dr. Condon did not know who above him might also share his thoughts on a longer-range plan.

It was noted that Mr. Gerstenmaier said that the solar electric propulsion was a key technology development for deep space missions. In addition, scooping up an asteroid has national defense from asteroids applications. Ms. Bartell suggested rewording what Mr. Gerstenmaier said to categorize who benefits: the planet benefits by planetary defense, for example. The nation benefits through national defense and NASA benefits through capability development for moving further into space. Dr. Siegel said that Mr. Gerstenmaier does say that, and it needs emphasis. Regarding how to help Administrator Bolden make the budget case for this, Ms. Bartell said that the discussion gave good relevance to NASA. Ms. Budden replied that the rest of the world cares less about NASA, but here is where NASA can benefit the world on something of concern. Dr. Condon added that if Administrator Bolden is interested in communicating the relevance of NASA, this is something he can state as being important to the world and planet. Ms. Budden suggested that HEOC write a statement that says the Committee recognizes that NASA and the NASA Administrator need increased advocacy to defend the NASA budget, and in the spirit of advocacy, HEOC recommends points related to a defined mission.

Mr. Bejmuk pointed out that planetary defense seems to come as two independent stories that NASA should integrate. It was added that the size of asteroid for the capture mission is not the size people should worry about, and the Russian one was bigger. However, this builds the capability to move an asteroid that really is dangerous. There are things NASA has not done previously, so it would be a step in that direction to note that this is something the Agency can do. The mission can be equally a step to Mars and to planetary defense, and a lot can be learned from it.

Dr. Longnecker said that whether or not the science community supports it, the Administration is going in this direction, and HEOC should make the case. If the Committee were to say it disagreed, none of it

would happen and the Office of Budget and Management will not go along with it. He suggested building on the concept. Mr. Malow added that it is also planetary science. If HEOC were to say anything, it should be along lines of "you have to sell this better." It will have a tough time otherwise. Dr. Siegel explained that the Office of Science and Technology Policy (OSTP) has written a letter stating that NASA does planetary defense. The budget was increased for Dr. Lindley Johnson, the NASA planetary scientist in charge of Near-Earth Object (NEO) detection.

Mr. Kohrs asked that a statement be written off-line in time for his meeting with the Administrator the next week.

He then noted that the research committee has been formed and has started up, though it needed some industry people. Dr. Longnecker said that it was very light on the medical side and also needed someone knowledgeable about that area. There are physician/scientists in radiation, but there is also a lot of skepticism in the science community about NASA's radiation program. The commercial side is more in the realm of CASIS.

Regarding risk, Mr. Kohrs found it interesting that the ISS risk is only considered a budget risk, in not being able to support crew transportation. He would report that as part of his briefing. Mr. Bejmuk added that in protecting the budget for commercial crew, NASA avoids being in a single contract exposure with the Soyuz system. The risk of losing an American on Soyuz expands the longer the United States keeps relying on it. Mr. Kohrs wondered whether, given that the Soyuz has flown many times, it is any more dangerous than a commercial vehicle that has never flown. As noted, NASA has never flown a vehicle that did not have some kind of dynamic test, which is why he wanted a longer discussion with Mr. Dumbacher. It was agreed to work this off-line. Mr. Bejmuk said that he would write something on limiting exposure.

Mr. Kohrs recalled that HEOC had made an integration recommendation. Things have begun improving, and the Committee should keep looking at it. The next level is a 2-3 hour discussion. He said that he would review the milestones. Mr. Bejmuk would write up his thoughts, and Ms. Budden would send hers.

The Committee had two recommendations:

1) Short Title of Recommendation: Elevate Priority of the Commercial Crew Development

Recommendation: NASA elevate priority of the Commercial Crew development and vigorously protect its funding, and reduce the number of funded providers. These NASA actions are needed to avoid undesired growth in Commercial Crew development time and risky increased reliance on a single provider, Soyuz.

Major Reasons for the Recommendation: Rapid establishment of US domestic crew transportation to the International Space Station is critically important to the sustainability of the US Human Space Program. NAC HEO Committee observed a very significant shortfall in Commercial Crew Program funding over the past two years, typically of order of 40% less than requested. During this funding shortfall period NASA has been funding three potential providers and maintaining 2017 schedule. NAC HEO committee's opinion is that continued reduction in Commercial Crew budget, funding the three providers, and maintaining 2017 schedule is not possible. The resulting outcome will be increased reliance on a single provider, Russian Soyuz, for transportation of US crew to ISS.

Consequences of No Action on the Recommendation: Increased risk to ISS due to dependency on single source provider for crew transport to and from station.

2) Short Title of Recommendation: Demonstrate and Articulate the Justification and Strategy for NASA's New Asteroid Initiative.

Recommendation: NASA should clearly demonstrate and articulate a strategy for the agency's new asteroid initiative that highlights the benefits that will be gained, making progress toward NASA goals while furthering science and technology and benefiting mankind. The agency should clearly demonstrate how the initiative will serve as a stepping stone to NASA's ultimate goal of a human mission to Mars. Potential benefits include involving operations that could apply to future missions, including life support and deep space habitability, advanced propulsion, complex ground and space operations, rendezvous in new gravitational environments, and sampling of small objects.

The agency should also demonstrate and articulate other potential benefits:
Benefit the United States by forging new industrial capabilities and international partnerships.
Benefit humankind by advancing technologies and operations that might someday assist in the development of a defense strategy for Earth-bound asteroids.

Major Reasons for the Recommendation: Current budget constraints result in federal agencies having to justify and fight for annual budgets. It is in NASA's best interests to demonstrate and clearly articulate the benefits of the asteroid initiative to the public and Congress in a way that accurately represents its merits.

Asteroid impact is in the public's mind after the recent event in Chelyabinsk, Russia. As part of the new initiative, NASA can take action to identify asteroids that might impact the Earth.

Consequences of No Action on the Recommendation: In the absence of a clearly demonstrated and accurately articulated justification, the new asteroid initiative might miss external interest, leading to loss of public and congressional support.

Public Comments

The HEOC held a public comment session.

Mr. Bayebete Rahman wondered if there might be advantage on commercial crew to combining crew and cargo in 2017. Mr. Kohrs explained that among the three commercial crew contractors, only one is involved with cargo. Of the two commercial cargo contractors, one is not involved with crew. There is no perfect correlation. Mr. Rahman suggested expanding to have that, since the business case is better for having both. Mr. Kohrs said that the person to answer that would be Mr. McAlister, but it would be difficult to do.

Mr. Juergen Nittner said that in preparing for a lunar mission as the next step off the planet, he thought NASA should stage from ISS and never have to purchase new Orions. The commercial partners could carry supplies to ISS and NASA could have several missions to the moon with one Orion capsule. A mission to the moon would be one SLS and back for re-entry. He asked what the lunar mission looks like with the SLS. Mr. Kohrs said that there are no plans for that. The Constellation program had a plan and had the lunar lander. However, in the SLS Orion program, there is no moon mission planned. Mr. Nittner thought the three SLSs could do a moon mission and speculated about how to accomplish this going to and from ISS. Mr. Kohrs said that the lunar mission is not in NASA's plans, and suggested Mr. Nittner contact the NASA office with his thoughts.

ADJOURN

The meeting adjourned at 5:44 p.m. The next meeting will be at the end of July 2013 in Washington, DC.

Appendix A
MEETING ATTENDEES

Committee Members
Present
Chair: Mr. Richard Kohrs
Co-Chair: Mr. Bohdan Bejmuk
Ms. Shannon Bartell
Ms. Nancy Ann Budden
Dr. Leroy Chiao*
Dr. Pat Condon
Mr. Joseph Cuzzupoli
Dr. David Longnecker
Mr. Richard Malow
Mr. James Odom
Mr. Bob Sieck*
Executive Secretary: Dr. Bette Siegel
Administrative Officer: Ms. Shawanda Robinson
**participated via teleconference*

NAC Science Committee Attendees at Joint Session
Chair: Dr. Wesley Huntress
Vice-Chair: Dr. Byron Tapley
Dr. Maura Hagan
Dr. Eugenia Kalnay
Dr. Eugene Levy*
Dr. Janet Luhmann
Dr. David McComas
Dr. Bradley Peterson
Dr. Meg Urry
Executive Secretary: Dr. T. Jens Feeley
**participated via teleconference*

NASA Attendees
Barbara Adde
Marc Allen
Louis Barbier
Michael Braukus
Marguerite Broadwell
Jonathan Cirtain
Al Condes
Dan Dumbacher
Bill Hill
Paul Hertz
Rick Irving
Cheryl May
Michael Meyer
Rashawn Mitchell

Marian Norris
David Porterfield
Diane Rausch
Christy Rivera
Jennifer Traxeu
Lucia Tsaoussi
Dan Woods

Non-NASA Attendees
Troy Dickinson
Michael Hauges
Mackenzie Lystrup
John Malas
Carle Pietres
Joan Zimmerman

WebEx Attendees
Gale Allen
Loretta Atkinson
Jack Burns
Stephen Clarke
Dennis Clay
Douglas Craig
James Dean
Jeff Foust
Steve Hirshorn
Alan Keiser
Michael Kelley
Rachel Kraft
Erin Mahoney
David Millman
Barbara Moody
Harmony Myers
Juergen Nittner, II
Patricia Rausch
Jennifer Read
Rita M. Sambruna
Lynn Servay
Kenneth Sidney
Marcia Smith
Jennifer Troxell
Dimitra Tsamis
Azita Valinia
Nicholas White

Appendix B

HEOC Committee Members

Mr. Richard Kohrs, Chair
Former Deputy Director, NASA Space Shuttle Program
Director, Space Station Freedom

Mr. Bohdan I. Bejmuk, Co-Chair
Aerospace Consultant,
Former Space Shuttle Orbiter Program Director, Boeing

Dr. Bette Siegel, Executive Secretary
NASA Headquarters

Ms. Shannon Bartell
Former Kennedy Space Center Safety & Mission Assurance Director

Ms. Nancy Ann Budden
Director for Special Operations Technology, Office of the Secretary of Defense

Dr. Leroy Chiao
Former NASA Astronaut and International Space Station Commander

Dr. Stephen "Pat" Condon
Aerospace Consultant,
Former Commander of the Ogden Air Logistics Center,
The Arnold Engineering Development Center and the Air Force Armament Laboratory

Mr. Joseph Cuzzupoli
Former Assistant Apollo Program Manager, Rockwell, and
Manager of the Space Orbiter Project

Mr. Tommy Holloway
Former Space Shuttle and International Space Station Program Manager

Dr. David E. Longnecker
Director, Health Care Affairs, Association of American Medical Colleges (AAMC)
Member, National Academy of Sciences Institute of Medicine (IOM)

Mr. Richard Malow,
Distinguished Advisor at the Association of University for Research in Astronomy (AURA)

Mr. James Odom
Former NASA Associate Administrator for Space Station Freedom

Mr. Bob Sieck
Former Space Shuttle Launch Director

Appendix C
Presentations

1. *HEOMD Overview*, Bill Gerstenmaier
2. *Status Report: SLPS NAC Subcommittee, CASIS,* D. Marshall Porterfield
3. *NASA Advisory Council Presentation,* Dan Dumbacher
4. *International Space Station Program Status,* Kirk Shireman
5. *Commercial Spaceflight Update,* Phil McAlister

Appendix D

Agenda

NASA ADVISORY COUNCIL
Human Exploration and Operations Committee
NASA Headquarters
PRC, Room 9H40
Washington, DC 20546-0001
PUBLIC MEETING

9:30 – 10:30 am	Status of Human Exploration and Operations; Joint Session w/the NAC Science Committee	Mr. William Gerstenmaier
10:30 – 11:00 am	Discussion	
11:00 – 11:15 am	BREAK	
11:15 am – 12:00 pm	Center for the Advancement of Science in Space/ Status of Research Subcommittee	Dr. D. Marshall Porterfield
12:00 – 1:15 pm	LUNCH	
1:15 – 2:15 pm	Status of Exploration Systems Development	Mr. Dan Dumbacher
2:15-2:30 pm	BREAK	
2:30 – 3:30 pm	Status of International Space Station	Mr. Kirk Shireman
3:30– 4:30 pm	Status of Commercial Spaceflight Development	Mr. Phil McAlister
4:30-4:45 pm	BREAK	
4:45-5:50 pm	Discussion and Recommendations	
5:50 – 6:00 pm	Public comments	
6:00 pm	ADJOURN	