Human Exploration and Operations Committee Status

Ken Bowersox
Committee Chair
July 27th, 2017
NAC HEO Committee Members

- Ms. Bartell, Shannon
- Mr. Bowersox, Ken, *Chair*
- Ms. Budden, Nancy Ann
- Ms. Caserta Gardner, Ruth G.
- Dr. Chiao, Leroy
- Dr Condon, Stephen "Pat"
- Mr. Cuzzupoli, Joseph W.
- Mr. Holloway, Tom
- Mr. Lon Levin
- Dr. Longenecker, David E.
- Mr. Lopez-Alegria, Michael
- Mr. Sieck, Robert
- Mr. Smith, Gerald
- Mr. Voss, James
Major Events Since Last NAC Meeting

- Decision not to add crew to EM-1 mission
- Reactivation of National Space Council
- Visits of Vice President to KSC and JSC
- Announcement of latest astronaut class
- SPX 11, Cygnus OA 7, Progress 66 and 67 cargo missions
- Soyuz 49 Crew Landing
- Multiple ISS Spacewalks
- Completion of SLS H2 tank test article
- Delivery for test of SLS main engine structural test article and Orion Stage Adapter structural test article
NAC HEO Meeting Summary April, 2015

NAC HEO Committee Meeting

Monday, July 24th, 2017

Human Exploration & Operations Status
ISS Status
Commercial Crew Program Status
Exploration Systems Status

Tuesday, July 25th, 2017

Joint Meeting with Science Committee
Future Human Exploration Plans
Science Mission Directorate Overview
Future Plans for Deep Space Telescopes
Servicing of Space Telescopes
Future Assembly and Servicing of Space Telescopes Study
Deep Space Gateway Science Workshop
Radiation and Deep Space Exploration
Space Communications and Navigation
Network Operations Accomplishments

• Maintained Network proficiencies (May 2017):
  DSN @ 98.9%      NEN @ 99.5%      SN @ 99.96%

• DSN Follow-the-Sun Operations (FtSO) Delivery and Soak installation occurred on June 26

• Sardinia Deep Space Antenna (SDSA) microwave feed installation completed May 2017

• The NEN Kennedy Uplink Station (KUS) antenna system successfully performed the first auto-tracking of a rocket on the May 1 SpaceX launch, and supported again on May 15

• New antenna in Alaska installed; electronics now in work

• The AS2 Site Acceptance Test successfully completed at ASF on April 6
  – Shadowed tracked AQUA, AURA, SMAP, AIM, GRACE 1/2, OCO-2, QUICKSCAT, SciSat, and JASON2

• SN upgrades to support EM-1 completed successful SRR, SDR, and ConOps reviews

• Now supporting ISS at 300 Mbps via Guam (Space Network)

• Perimeter Surveillance and Intrusion Detection System (PS&IDS) ORR successfully completed on June 27
FY17-FY18 Support Activity
Launch Services Program: FY 2017 Accomplishments

- **GOES-R**
  - Nov 2016

- **CYGNSS**
  - Dec 2016

- **OA-7**
  - April 2017

- **CRS SPX 11**
  - June 2017

- **TDRS-M**
  - Aug 2017

- **JPSS-1**
  - Oct 2017

- **ICON**
  - Nov 2017

- **GRACE-FO**
  - Dec 2017

- **GOES-S**
  - Mar 2018

- **TESS**
  - Mar 2018

- **InSight**
  - May 2018

- **ICESat-2**
  - Sep 2018

- **PSP**
  - July 2018
CCP – SpaceX Accomplishments

- **Certification Products**
  - Numerous Verification Events approved and Phase II Hazard Reports are progressing
  - Received updated deliveries of Configuration Management, Risk Management, and Safety and Reliability Plans

- **Demonstration & Test**
  - Buck Mock-up returned from vendor after interior panel installation in July
  - 2 Hardware-in-the-Loop (HITL) tables assembled in support of software testing with flight computers and vehicle Remote Input Output units
  - Performed acceptance testing of Demo-1 components including heatshield
  - Continued Validation Propulsion Module Build up for McGregor test
  - First Demo-1 joint simulation was performed with MCC-H and MCC-X
  - Lightening Protection System Installed at LC-39A, and crew access arm and white room installation planned for late fall
CCP – Boeing Accomplishments

- **Certification Products**
  - Numerous Verification Closure Notices and Phase II Hazard Reports have been approved
  - Received updated deliveries of Configuration Management, Risk Management, and Safety and Reliability Plans

- **Demonstration & Test**
  - Additional arc-jet testing of Boeing Lightweight Ablator (BLA) shoulder completed
  - Two Land Landing Qualification Tests completed
  - Continued progress with Structural Test Article campaign
    - Proof Pressure Test complete
    - Service Module Fixed Base Structural Test complete
    - Ascent Cover and Landing/Recovery Systems Shock Tests in progress
    - Commercial Crew Transportation Services Modal testing
Flame Trench Refurbishment project at LC39B - The final brick on the flame trench walls was laid on May 9, completing the installation of all 93,645 refractory bricks.

A construction worker installs the final brick on the north side of the flame trench at Launch Complex 39B at NASA's Kennedy Space Center in Florida.

EM1 crew module completed clean room operations in May 2017

On May 15, the Core Stage Engine Section (ES) Structural Test Article (STA) arrived at the MSFC dock from Michoud Assembly Facility (MAF) on the NASA Barge, Pegasus. The ES STA was unloaded and transported via the Engine Section Transporter to the Load Test Annex Extension in Building 4619 on May 17 where it will undergo structural qualification testing. This is a significant milestone since this is the first of four STAs to be delivered to MSFC for testing.
ESD Accomplishments – June 2017

On June 15 the abort motor team successfully fired the Qualification Motor-1 (QM-1) motor at the Orbital-ATK facility in Promontory, Utah. This was a “hot” motor conditioned to ~100f and it burned for the full 5 seconds and generated the expected 480k lbf of thrust. QM-1 marks the beginning of the motor qualification program for the Launch Abort System.

In June 2017, the heat shield tile bonding was complete at the Operations and Checkout building at Kennedy Space Center.

On June 22, members of the Johnson team participated in a Vacuum Pressure Integrated Suit Test to verify enhancements to the suit will meet test and design standards for the Orion spacecraft. During this test, the suit is connected to life support systems and then air is removed from Johnson’s 11-foot thermal vacuum chamber to evaluate the performance of the suits in conditions similar to a spacecraft. The suit will contain all the necessary functions to support life and is being designed to enable spacewalks and sustain the crew in the unlikely event the spacecraft loses pressure.
Technicians lifted the liquid hydrogen tank structural qualification test article into a cleaning cell at NASA’s Michoud Assembly Facility in New Orleans where its insides will be thoroughly cleaned, coated and dried to certify the process for the following flight article. This represents a transition from activation/facility design to Process Development and Production operations with full-scale hardware.

As of June 16, The Mobile Launcher (ML) EIT successfully installed all eight (8) Vehicle Support Posts (VSPs), two Aft Skirt Electrical Umbilicals (ASEUs), and two Aft Skirt Purge Umbilicals (ASPUs) on the main deck on the ML. The VSPs weigh ~ 11,000 lbs each and 4 VSPs hold and support each Solid Rocket Booster (SRB). They will be instrumented with strain gauges to measure loads during vehicle stacking, rollout and launch. The ASEUs weigh ~ 3600 lbs each and connect to the bottom outer edge of the SLS rocket’s boosters and provide electrical power and data connections to the SLS rocket until lift off. The ASEUs also carry signals to the Launch Release System (LRS). The ASPUs connect to the SLS rocket at the bottom outer edge of each booster and provide a heated GN2 purge to remove potentially hazardous gases and maintain temperature range of components. The ASPUs will be connected during stacking operations in the Vehicle Assembly Building and will remain connected until T-0.
Off the coast of Galveston, Texas, a NASA and Department of Defense team tested Orion exit procedures in a variety of scenarios July 10-14.

The Orion Stage Adapter (OSA) Structural Test Article (STA) was transported onboard the NASA Super Guppy aircraft to Denver, Colorado, on July 11 for use by the Orion Program. The effort was a collaboration between supporting MSFC organizations, the Redstone Airfield, and the Orion and Super Guppy organizations at JSC. The media event associated with the shipment included coverage on local television networks and the internet. In addition, the Super Guppy crew performed a fly-over of MSFC that provided an opportunity for the MSFC team to see this unique aircraft in flight. Use of the OSA STA provides a significant cost avoidance for Orion and a flight-like interface for planned modal, acoustic, and stiffness tests.
Increment 52 Overview: Crew

50S Dock 4/20/17
50S Undock 9/2/17

Peggy Whitson
FE (US) – 49S
(CDR Inc 51)

Fyodor Yurchikhin
Soyuz CDR (R) – 50S
(CDR Inc 52)

Jack Fischer
FE (US) – 50S

51S Dock 7/28/17
51S Undock 12/14/17

Sergey Ryzanski
Soyuz CDR (R) – 51S

Randy Bresnik
FE (US) – 51S

Paulo Nespoli
FE (US) – 51S
**Increments 51 & 52**

**Increment 51: 54 days**
- Stage 51–3: 485 undock to 50S dock: 10 days
- Stage 51–5: 50S dock to 495 undock: 44 days
- USOS EVAs: ExpCA EVA, EXT–1 R&R
  - Cargo Vehicles:
    - OA–7 Berth (4/22)
    - NREP
    - MSG throughput pending OA–7 (Osteomics, Magnetic 3D, ABC)
    - NRCSD pending OA–7
    - JSSD pending Spx–11
    - Human Life Science
    - Grasp
    - Sarcobol
    - Spx–11 science (RR–5, ROSA, MUSES, NICER)
    - Maintenance/Outfitting:
    - UPA troubleshooting/DA change out
    - JSv10, JS Router Upgrades
    - Col Cycle 14.1 Software Update
    - MBSU 2 Robotic R&R
    - SSC client upgrade to ZBook
    - Cupola Scratch Pane R&Rs
    - Galley Rack Food Warmer Install

**Increment 52: 93 Days**
- Stage 52–3: 495 undock to 51S dock: 55 days
- Stage 52–6: 51S dock to 50S undock: 37 days
- EVAs (7/28–9/2)
  - Russian EVA #43 to install/remove experiments and deploy satellites (8/17)
  - Cargo vehicles:
    - Spx–12 berth (8/13), release (9/10)
  - Science/Utilization:
    - Human Life Science
    - Spx–12 (CREAM, Kaber/KE2M Deploy)
    - MSG throughput (Rodsent, Antibody Conjugates)
    - Cool Flames, LMM Biophysics
    - Maintenance/Outfitting:
    - WPA MF bed change out (on watch list)
    - N3 CCAA Water Sep R&R (planned mid-July)
    - Cupola Scratch Pane R&R and Bump Shield install
    - USOS Reconfiguration continuation
    - UPA Firmware 6.3 upgrade
    - RPCM firmware update
    - MBSU 1-Level maintenance
    - Robotic S0S inspection
    - IP/ENG install into Express Rack 4, WORF, and HRF Racks

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**INCREMENTS 51 & 52**

**Pre-decisional, Internal Use Only**

Updated 5/26/2017

Updated 6/29/2017

https://iss-www.pnc.nasa.gov/mrw/m/nf/incl_51_52/
External Active Thermal Control System (EATCS) Loop B has had a trending leak since ~2013.

Current Loop B leak rate was in the range of 75 – 115 lbs/year NH3 (Not a gross leak)
- Leak considered small but rate was accelerating

Radiator flex line region around RBVM P1–3–2 hardware appear to have ammonia leakage.
- Robotic External Leak Locator (RELL) operations in November 2016 indicated elevated ppNH3 in vicinity of P1–3–2 and February 2017 operations indicated elevated ppNH3 in vicinity of radiator jumpers from P1–3–2 RBVM.
- Inc 50 EPIC SPDM Lube EVA performed close up inspections of the suspect RBVM hardware in this area for evidence of ammonia.
  - GoPro video showed flakes that appeared to come from near F128/M4 3/4 inch QD

- Post P1–3–2 isolation and vent, the leak rate has decreased to ~0.9 lbm/year. Teams continue to trend data
  - Note: Loop A leak rate is steady at 1.4 lbm/year following the Pump Module R&R in late 2013.
- Forward work to assess root cause and replacement flex line hardware options.
Physical Sciences Recent Accomplishments

♦ Cool Flames Investigation (CFI) Continuing Operations in Combustion Integrated Rack (CIR)
  • Ops began Dec 2017; Completed ~20% of desired test matrix (minimum success achieved); details on Project Highlight chart

♦ Light Microscopy Module Biophysics 1 and 3 (LMM BIO-1, -3) Operations Completed
  • LMM BIO, an LMM/Fluids Integrated Rack (FIR) investigation, is a CASIS collaboration (SLPSRA funded research and HW development w CASIS crew time), to study crystallizing proteins, which may be used to design new drugs and identify which types of crystals benefit from growth in microgravity. High quality, space-grown crystals could improve research for diseases, as well as microgravity-related problems such as radiation damage, bone loss and muscle atrophy.

♦ Zero Boil Off Tank (ZBOT) launched on OA-7
  • Exploration critical investigation to be run in Microgravity Science Glovebox (MSG), that will anchor fluid dynamics models that will enable efficient and effective cryogenic fluids storage and management in space propulsion systems.
NICER and SEXTANT

Installed 6 weeks ago on ISS and now operational

- Neutron Star Interior Composition Explorer (NICER) instrument will study the physics of neutron stars (pulsars), providing new insight into their nature and behavior.
  - Neutron stars emit X–ray radiation, enabling the NICER technology to observe and record information about their structure, dynamics and energetics.
- SEXTANT – instrument will use 56 telescopes to detect X–ray photons from pulsar beams of light to estimate their arrival times. With these measurements, the system will stitch together an on–board navigational solution using specially developed algorithms – GPS for the cosmos.
EXPANDING HUMAN PRESENCE IN PARTNERSHIP
CREATING ECONOMIC OPPORTUNITIES, ADVANCING TECHNOLOGIES, AND ENABLING DISCOVERY

Now
Using the International Space Station

2020s
Operating in the Lunar Vicinity (proving ground)

Phase 0
Continue research and testing on ISS to solve exploration challenges. Evaluate potential for lunar resources. Develop standards.

Phase 1

Phase 2
Complete Deep Space Transport and conduct yearlong Mars simulation mission.

Phase 3 and 4
Begin sustained crew expeditions to Martian system and surface of Mars.

After 2030
Leaving the Earth-Moon System and Reaching Mars Orbit
STRATEGIC PRINCIPLES FOR SUSTAINABLE EXPLORATION

• **FISCAL REALISM:** Implementable in the near-term with the buying power of current budgets and in the longer term with budgets commensurate with economic growth;

• **SCIENTIFIC EXPLORATION:** Exploration enables science and science enables exploration; leveraging scientific expertise for human exploration of the solar system.

• **TECHNOLOGY PULL AND PUSH:** Application of high TRL technologies for near term missions, while focusing sustained investments on technologies and capabilities to address the challenges of future missions;

• **GRADUAL BUILD UP OF CAPABILITY:** Near-term mission opportunities with a defined cadence of compelling and integrated human and robotic missions, providing for an incremental buildup of capabilities for more complex missions over time;

• **ECONOMIC OPPORTUNITY:** Opportunities for U.S. commercial business to further enhance their experience and business base;

• **ARCHITECTURE OPENNESS AND RESILIENCE:** Resilient architecture featuring multi-use, evolvable space infrastructure, minimizing unique developments, with each mission leaving something behind to support subsequent missions;

• **GLOBAL COLLABORATION AND LEADERSHIP:** Substantial new international and commercial partnerships, leveraging current International Space Station partnerships and building new cooperative ventures for exploration; and

• **CONTINUITY OF HUMAN SPACEFLIGHT:** Uninterrupted expansion of human presence into the solar system by establishing a regular cadence of crewed missions to cis-lunar space during ISS lifetime.
The International Space Station (ISS) is a platform for deep space exploration, scientific research, economic growth and global diplomacy. ISS brings the world together to discover, develop and advance solutions for a better life both here on Earth and in space.
**PHASE 1 PLAN**

Establishing deep-space leadership and preparing for Deep Space Transport development

**Deep Space Gateway Buildup**

<table>
<thead>
<tr>
<th></th>
<th>EM-1</th>
<th>Europa Clipper</th>
<th>EM-2</th>
<th>EM-3</th>
<th>EM-4</th>
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<td><strong>2019 - 2025</strong></td>
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<tr>
<td>SLS Block 1</td>
<td>SLS Block 1B Cargo</td>
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<td>Crew: 0</td>
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<td>CMP Capability: 0</td>
<td>CMP Capability: 8-9t</td>
<td>CMP Capability: 10t</td>
<td>CMP Capability: 10t</td>
<td>CMP Capability: 10t</td>
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<td>40kW Power/Prop Element</td>
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<td>Europa Clipper (subject to approval)</td>
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<td>SLS Block 1B</td>
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<td>Crew: 4</td>
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<td>CMP Capability: 10t</td>
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<td><strong>Known Parameters:</strong></td>
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<td>Gateway to architecture supports Phase 2 and beyond activities</td>
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<tr>
<td>International and U.S. commercial development of elements and systems</td>
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<tr>
<td>Gateway will translate uncrewed between cislunar orbits</td>
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<td>Ability to support science objectives in cislunar space</td>
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<td><strong>Open Opportunities:</strong></td>
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<td>Order of logistics flights and logistics providers</td>
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<td>Use of logistics modules for available volume</td>
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<tr>
<td>Ability to support lunar surface missions</td>
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**These essential Gateway elements can support multiple U.S. and international partner objectives in Phase 1 and beyond.**
PHASE 2

Deep Space Gateway (DSG)

Orion

Deep Space Transport (DST)
### Transport Delivery

<table>
<thead>
<tr>
<th></th>
<th>EM-6</th>
<th>EM-7</th>
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<tr>
<td>2027</td>
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<tr>
<td>SLS Block 1B Cargo P/L Capability: 41t TLI</td>
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### Transport Shakedown

<table>
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<tr>
<th></th>
<th>EM-8</th>
<th>EM-9</th>
<th>2028 / 2029</th>
<th>EM-10</th>
<th>EM-11</th>
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<tbody>
<tr>
<td>DST checkout in NRHO 191-221 days</td>
<td>DST: logistics &amp; refueling</td>
<td>DST: shakedown in cislunar space with return to DSG in NRHO 300-400 days</td>
<td>DSG: continued operations in cislunar space</td>
<td>DST: Mars transit and return to DSG in NRHO</td>
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### Mars Transit

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<tr>
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<th>2030+</th>
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<tr>
<td>SLS Block 2 Cargo P/L Capability: 45t TLI</td>
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### Known Parameters:
- DST launch on one SLS cargo flight
- DST shakedown cruise by 2029
- DST supported by a mix of logistics flights for both shakedown and transit
- Ability to support science objectives in cislunar space

### Open Opportunities:
- Order of logistics flights and logistics providers
- Shakedown cruise vehicle configuration and destination/s
- Ability to support lunar surface missions
Space Radiation Challenge

- Space radiation produces potential increased health risks of cancer, cardiovascular disease, CNS effects, and acute radiation syndromes
  - Damage to cells is different from terrestrial sources of radiation
  - Translating experimental data to humans

- Understanding Individual Radiation Sensitivity
  - Small Crew Population

- SMD and HEOMD measurements to accurately characterize the space radiation environment are needed to optimize mitigation strategies
NASA Crew Mission Doses

 lesbians

0 200 400 600 800
Mission Dose

0.1
1
10
100
1000

Badge Dose, mGy
Effective Dose, mSv
Biodosimetry, mGy-Eq
Mars Mission, mSv

NASA Experience:
• Single ISS mission approximately 1/10 of Mars mission exposure
• Many crew with multiple missions have accumulated 1/3 of Mars exposure risk

New Radiation Transport Code Approach Includes transport of additional particle types (HZETRN)
- More shielding may not reduce risk – optimum shield thickness takes shielding out of larger trade space
- Once minimum exposure is achieved, remaining risk must be reduced by mission duration, biological countermeasures, or acceptance

Validation Uses Radiation Environmental Data
- Comparisons to measurements in Earth’s atmosphere, MSL RAD, and ISS RAD as well as with Monte Carlo transport models
- STMD Thick Shield Project beam experiments underway at NSRL
HEOC/SC Joint Recommendation: Mitigating Space Radiation Risk

Recommendation:
The committees recommend that NASA accelerate efforts to reduce the radiation risk for future crews by exploring novel concepts for radiation shielding and improving deep space propulsion that would reduce transit time.

Major Reasons for the Recommendation
The Science and HEO Committees met jointly to get an update on the expected radiation exposure for deep space missions.

Current data shows that the deep space transit to Mars would expose the crew to roughly two to three times the radiation dose received on a similar length mission aboard ISS, and approximately the same level exposure as ISS while on the surface of Mars. For a two to three year transit to and from Mars as currently envisioned for the deep space transport, an increase in lifetime cancer risk of approximately 10% could be expected for the crew members.

Consequences of No Action on the Recommendation
Greater health risk must be accepted for Mars human exploration missions.

To NASA Administrator
• ISS is a critical test bed for development of systems that will be used for deep space exploration. While projections show that the work should be complete by 2024, the committee believes that it is likely that exploration development work on ISS will need to be continued until 2028 or later.
Finding on ISS - Background

• ISS is an excellent platform for science activity in Low Earth Orbit. As ISS matures, the onboard science activity is also increasing.
• Uncertainty of ISS end date is likely to result in reduced interest by the science community because of the lead time to develop and execute research projects.
• Reduced operational efficiency should be expected for one to two years prior to ISS end of life due to the work required to prepare for termination of the ISS.
• Uncertainty of ISS end date makes it more difficult for potential commercial partners to obtain funding and develop the market for services.
• There are many options for phasing out work on ISS, and it may be more reasonable to change ISS to reduce its cost of operation rather than to sharply stop work. Ideally, the end of support for the ISS would be determined by clear criteria for its required use, and availability of commercial alternatives rather than an arbitrary date.
ISS is a critical facility for development of systems that will be used for deep space exploration, especially for life support systems. Current projections show approximately two years of run time on deep space exploration life support systems on board ISS – in preparation for what may be a three year crewed mission to Mars in the 2030s. While the official commitment to ISS currently ends in 2024, the committee believes that it is likely that exploration development in low earth orbit will need to be continued past 2024.

Ideally, the end of government support for the ISS would be determined by clear criteria for its required use, availability of commercial alternatives and would be a gradual reduction in support rather than a sharp cutoff at a fixed date. Early understanding of ISS availability after 2024 will improve the station’s science utilization and improve the likelihood that commercial providers will be able to sustain low earth orbit operational capability after the government reduces support.
Discussion Areas

- Deep space telescope servicing and assembly
- Radiation exposure and countermeasures on exploration missions
- Science missions at the Deep Space Gateway
- Amount of work ahead for NASA – especially commercial crew
- Affect of current processes on decision velocity
- Use of clear criteria for work to be performed on ISS and available alternatives to determine phase out of government funding
The committee observed that a great deal of technical progress has been made on HEO programs since our last meeting, and continues to be impressed by the amount of work being managed by the directorate team.

NASA has a lot of work ahead to accomplish the goals being set out for deep space exploration, while at the same time developing commercial crew capabilities and managing the International Space Station. Increased emphasis on organizational efficiency, stable requirements and decision velocity will be critical to meet the current schedules.
HEO Committee Concerns

• Budget uncertainty and lack of flexibility in use of funds continues, and now has greater potential for program disruption as SLS and Orion get closer to launch.

• The Deep Space Gateway could be capable of other deep space missions, in addition to its prime mission as a node for development and staging of the Deep Space Transport. The committee is concerned that requirements for the Gateway may grow excessively during the development phase, and encourages the HEO team to maintain focus on the prime mission when developing the Gateway’s system requirements.

• Bureaucratic processes that NASA imposes on itself do not always add value to balance their load on the organization and are a threat to accomplishment of NASA’s exploration mission.

• The number and intensity of current reviews of the HEO programs are not helpful and use too many precious resources.

• Low SLS and Orion Launch rate pose future risks for proficiency of the operations team and reduce program resilience in the event of mission failure.
Special Topics at Future HEO Committee Meetings

• Future Special Topics:
  
  – International Participation in future human exploration
  – ISS after 2024 and ISS commercialization efforts ***
  – Launch readiness process for commercial crew
  – ASAP insight to the Commercial Crew Program ***
  – Systems Engineering and Integration for Exploration Systems
  – Deep space telescopes and possible servicing missions ***
  – Planetary protection
  – Radiation exposure on exploration missions and countermeasures ***
  – Program decision making approach and independent technical authorities
  – Exploration EVA Capability

*** Discussed at this meeting – July 2017
www.nasa.gov