NAC HEO Committee Members

- Ms. Bartell, Shannon (Unable to Attend)
- Mr. Bowersox, Ken, **Chair**
- Ms. Budden, Nancy Ann
- Dr. Chiao, Leroy (Unable to Attend)
- Dr Condon, Stephen "Pat"
- Mr. Cuzzupoli, Joseph W.
- Mr. Holloway, Tommy (Unable to Attend)
- Mr. Lon Levin
- Dr. Longenecker, David E.
- Mr. Lopez-Alegria, Michael (Unable to Attend)
- Mr. Malow, Richard N.
- Mr. Odom, Jim (James)
- Mr. Sieck, Robert
- Mr. Voss, James
NAC HEO Committee Meeting

Monday, April 14, 2014

Status of Human Exploration and Operations
Research Subcommittee Report
International Space Station Status
Discussion of NASA’s Guidance on Program Management
NPR 7120
Status of Commercial Spaceflight

April 15, 2014

Status of Exploration Systems Development
Public comments and input
Committee Discussion and Deliberation
NASA Advisory Council
Human Exploration and Operations Committee

Research Subcommittee Report
One Year Study and Genome Project

Bradley M. Carpenter, PhD.
Chief Scientist, Space Life and Physical Sciences
Human Exploration & Operations Mission
Directorate
Research Subcommittee of the HEO Committee

NASA Advisory Council Recommendation in March, 2012 to create 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.”

From the Research Subcommittee Terms of Reference-
The Research Subcommittee will support the HEO Committee in its missions by meeting the following objectives:
1. Provide advice and recommendations on the overall objectives, approach, content, and structure of research activities in HEOMD.
2. Provide assessments on the effectiveness of relationships between HEOMD’s missions and stakeholders in the research and educational sectors.
HEOC Research Subcommittee

Dr. David Longnecker, M.D., is the chair of the subcommittee. He is a member of the Human Exploration and Operations Committee. He is a Director of the Association of American Medical Colleges, and is the Robert D. Dripps Professor Emeritus of Anesthesiology and Critical Care at the University of Pennsylvania. He has served as President of the American Board of Anesthesiology, and is a member of the Institute of Medicine. At the IOM, he has served as chair of the Standing Committee on Aerospace Medicine and the Medicine of Extreme Environments.

Dr. Robert A. Altenkirch currently serves as president of The University of Alabama in Huntsville. Prior to this appointment, he served as president of New Jersey Institute of Technology. Dr. Altenkirch earned his B.S. from Purdue University, an M.S. from the University of California, Berkeley, and his Ph.D. from Purdue. Other previous positions include vice president for research at Mississippi State University and dean of the College of Engineering and Architecture at Washington State University.
Dr. M. Katherine Banks is the Dean of Engineering at Texas A&M University. Previously she had been head of the School of Civil Engineering at Purdue University. At Purdue, she also served as director of the EPA Hazardous Substance Research Center. She is a Fellow of the American Society of Civil Engineers and served as editor-in-chief for the *ASCE Journal of Environmental Engineering* and associate editor of the *International Journal of Phytoremediation*.

Dr. Jeffrey A. Hoffman is a Professor of the Practice in the Department of Aeronautics and Astronautics at the Massachusetts Institute of Technology. At MIT he also directs the Massachusetts Space Grant Consortium. He served as the NASA Europe Representative, and flew on five Shuttle missions as a NASA astronaut. Before joining the astronaut corps, he worked as an astrophysicist, with a focus on gamma ray and x-ray astronomy.
HEOC Research Subcommittee

Dr. Terri L. Lomax serves as the Vice Chancellor for Research, Innovation and Economic Development at North Carolina State University. Previous positions include Deputy Associate Administrator for Research in the Exploration Systems Mission Directorate, and Director of the NASA Fundamental Space Biology Division. She was a member of the faculty at Oregon State University from 1987 until 2006, with research interests in plant physiology and genetics.

Dr. Stein Sture is Vice Chancellor for Research at the University of Colorado, Boulder. He also is the Huber and Helen Croft Endowed Professor in the Department of Civil, Environmental, and Architectural Engineering in the College of Engineering and Applied Science. He has been a faculty member at CU Boulder since 1980. His fields of expertise are in the areas of experimental and analytical modeling in solid mechanics, geomechanics, computational geotechnics, and geotechnical engineering.
Dr. Kathryn C. Thornton is a Professor at the University of Virginia in the School of Engineering and Applied Science in the Department of Mechanical and Aerospace Engineering. She served from 1999 until 2012 as the Assistant Dean and later Associate Dean for Graduate Programs. Selected as an astronaut candidate by NASA in May 1984, Thornton is a veteran of four space flights. Since leaving NASA, Thornton has served on several review committees and task groups, including the National Research Council Study: Science Opportunities Enabled by Constellation (2007) as co-chair.
Research Subcommittee Activities

First meeting 17 April, 2013 – videocon
   Organizational focus- Introductions, overview, goals and priorities

31 July 2013 – Washington DC
   Relationship between research and technology- SLPS, HRP, and Advanced Exploration Systems.

24 February 2014 – Washington DC
   Role of SLPS in HEO goals, SLPS research planning, ISS resource planning. Open source science
Biological and Physical Sciences

- NASA's Space Life and Physical Sciences Research and Applications Division (SLPS) has been formulated to execute high quality, high value research and application activities in the areas of:
  - Space Biology
  - Physical Sciences
  - Human Research

- These programs conduct fundamental and applied research to advance basic knowledge and to support human exploration in the environment of space.

- Division serves as the Agency liaison with the ISS National Laboratory management organization, the Center for the Advancement of Science in Space (CASIS).
Response to the Decadal Survey: Perspectives and Approaches for Going Forward

- Chartered by Congress the National Academy of Science Commissioned a National Research Council decadal survey of NASA Life and Physical Sciences

- The Resulting report serves the SLPS Division in HEO as a guideline for developing applied and fundamental research that serves to promote the NASA human exploration mission

- Decadal recommendations serve the ultimate direction in prioritization of ISS research efforts coming from the SLPS Division at HQ

- NASA/SLPS is directly responsible back to the NAS/NRC and congress in how the recommendations are addressed.
<table>
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<tr>
<th>Human Health and Performance Risks Coordinated with all International Partners</th>
<th>Mission</th>
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<td><strong>Musculoskeletal</strong></td>
<td>Long-term health risk of Early Onset Osteoporosis; Mission risk of reduced muscle strength and aerobic capacity</td>
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<td><strong>Sensorimotor</strong></td>
<td>Mission risk of sensory changes/dysfunctions</td>
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<td><strong>Ocular Impairment</strong></td>
<td>Mission and long-term health risk of Microgravity-Induced Visual Impairment and/or elevated Intracranial Pressure (VIIP)</td>
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<td><strong>Nutrition</strong></td>
<td>Mission risk of behavioral and nutritional health due to inability to provide appropriate quantity, quality and variety of food</td>
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<td><strong>Autonomous Medical Care</strong></td>
<td>Mission health risk due to inability to provide adequate medical care throughout the mission (Includes onboard training, diagnosis, treatment, and presence/absence of onboard physician)</td>
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<td><strong>Behavioral Health and Performance</strong></td>
<td>Mission and long-term behavioral health risk.</td>
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<td><strong>Space Radiation</strong></td>
<td>Long-term risk of carcinogenesis and degenerative tissue disease due to radiation exposure</td>
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<td><strong>Toxicity</strong></td>
<td>Mission risk of exposure to a toxic environment without adequate monitoring, warning systems or understanding of potential toxicity (dust, chemicals, infectious agents)</td>
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<tr>
<td><strong>Autonomous Emergency Response</strong></td>
<td>Medical risks due to life support system failure and other emergencies (fire, depressurization, toxic atmosphere, etc.), crew rescue scenarios</td>
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<tr>
<td><strong>Hypogravity</strong></td>
<td>Long-term risk associated with adaptation during IVA and EVA on the Moon, asteroids, Mars (vestibular and performance dysfunctions) and post-flight rehabilitation</td>
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*Not limiting* indicates that the mission risk is not considered limiting. *Increased risk* indicates a risk that is not limiting, but increased. *Potentially limiting* indicates that the risk is potentially limiting.
ISS Crew: Scott Kelly, Mikhail Kornienko Sign On For One-Year Mission

By: Tariq Malik
Published: 11/26/2012 08:12 AM EST on SPACE.com

A veteran NASA space commander and Russian cosmonaut have signed on for the ultimate space voyage: a yearlong trip on the International Space Station.

American astronaut Scott Kelly and Russian cosmonaut Mikhail Kornienko will launch on the one-year space station flight in spring 2015 and return to Earth in spring 2016, NASA officials announced today (Nov. 26). They will begin their mission training in early 2013.
Twin Sons: Scott Kelly & Mark Kelly
Selected Twin Study Investigations

- Immunome Changes in Space
- Longitudinal integrated multi-omics analysis of the biomolecular effects of space travel
- Proteomic Assessment of Fluid Shifts and Association with Visual Impairment and Intracranial Pressure in Twin Astronauts
- Differential effects on telomeres and telomerase in twin astronauts associated with spaceflight
- Metagenomic Sequencing of the Bacteriome in GI Tract of Twin Astronauts
- Comprehensive whole genome analysis of differential epigenetic effects of space travel on monozygotic twins
- The Landscape of DNA and RNA Methylation Before, During, and After Human Space Travel
- Cognition on Monozygotic Twin on Earth
- Metabolomic And Genomic Markers Of Atherosclerosis As Related To Oxidative Stress, Inflammation, And Vascular Function In Twin Astronauts
- Biochemical Profile: Homozygous Twin control for a 12 month Space Flight Exposure
Perform Astro-Omics / Systems Biology

Genomics

Transcriptomics, (RNA)

Epigenomics

Proteomics

Metagenomics

Metabolomics
Finding: The NASA Advisory Council (NAC) endorses NASA’s research initiatives that explore the genomic implications of space flight, including the proposed Twins Study and development of an open source approach for the Space Life and Physical Sciences GeneLab initiative. The Research Subcommittee of the HEO Committee will request regular updates to these initiatives at each of its next several meetings.
NAC:
International Space Station Program Status

April 2014
Michael T. Suffredini
Manager, ISS Program
38 Soyuz Launch/Expedition 39
March - September 2014

Vehicle: 38 Soyuz
Launch: March 25, 2014; 4:14 pm CDT (with 4 rendezvous)
Docking: March 25, 2014; 10:14 pm CDT
Undock/Landing: September 11, 2014

38 Soyuz Crew
Alexander Skvortsov, Soyuz Commander
Oleg Artemiev, Flight Engineer
Steve Swanson, Flight Engineer

38 Soyuz crew will join 37 Soyuz crew already on orbit

Vehicle: 37 Soyuz
Launch/Docking: November 6, 2013
Undock/Landing: May 14 2014

Mikhail Tyurin, Soyuz Commander
Koichi Wakata, Flight Engineer
Rick Mastracchio, Flight Engineer
Expedition 39 Objectives
(March 2014 – May 2014)

Perform an average of 39.4 hrs/week for payload investigations. New investigations include:

- **Hybrid Training** - Will use electrodes on the arms to stimulate muscles to work against each other and load the bones while exercising to reduce muscle atrophy and bone loss during long space missions. The apparatus, similar to what chiropractors use on Earth, will be placed on one arm so doctors can compare regular exercise against exercise plus electrostimulation.

- **FASTER (Facility for Absorption and Surface Tension)** - investigates how surfactants (surface acting agents that reduce the surface tension of water) will affect the physical chemistry properties and emulsion stability of droplet interfaces.

- **T-Cell Activation in Aging** - Seeks the cause of a depression in the human immune system while in microgravity. T-cells, a type of white cell, are coated with chemical receptors that must trigger together to activate the body’s immune system properly. T-cells from flight crews and ground volunteers in a range of ages are analyzed to determine changes in protein production and gene response on the ground and in microgravity.

- **Cell Mechanosensing** - Will identify gravity sensors in skeletal muscle cells and help develop countermeasures to muscle atrophy, a key space health issue. Scientists believe that the lack of mechanical stress from gravity causes tension fluctuations in the plasma membrane of skeletal muscle cells, in turn changing the expression of key proteins and genes and allowing muscles to atrophy.

- **Gravi 2 (Threshold Acceleration for Gravisensing – 2)** - Grows lentil seedling roots under various gravity conditions on board the International Space Station (ISS) to determine the amount of acceleration force sufficient to stimulate the direction of root growth.

- **OPALS (Optical Payload for Lasercomm Science)** - will demonstrate and test optical communications technologies by transferring video data from the OPALS hardware on the ISS to a ground. Optical communication is an emerging technology where the data is modulated onto laser beams, which offers the promise of much higher data rates than what is achievable with radio-frequency (RF) transmissions.

- **Support planned visiting vehicle traffic:**
  - 38S Launch, March 25
  - 38S Dock, March 25
  - 54P Unberth, April 7
  - 55P Launch & Dock, April 9
  - SpX-3 Launch, April 14
  - SpX-3 Berth, April 16
  - 53P Unberth for KURS-NA test, April 23
  - 53P Reberth, April 25
  - Orb-2 Launch, May 6
  - Orb-2 Berth, May 9
  - Note: Orb-2 launch/berth will move to June if SpX-3 launches in April
  - 37S Undock, May 13

- **Significant tasks:**
  - National Geographic “Live from Space” event. (completed March)
  - X2R12.1 transition (completed March)
  - Install HDEV and OPALS (external payloads from SpaceX-3)
  - 53P KURS-NA test
  - SMILES relocate (JEM Exposed Pallet using JEM RMS)
Pre-Decisional, For Internal Use Only

OC/OZ reconciliation is completed as of Week 3

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Executed through Increment Wk (WLP Week) 3 = 2.8 of 24.8 work weeks (11.29% through the Increment)

USOS IDRD Allocation: 960.5 hours
OOS USOS Planned Total: 963.58 hours
USOS Actuals: 51.58 hours
5.37% through IDRD Allocation
5.35% through OOS Planned Total

Total USOS Average Per Work Week: 18.42 hours/work week
Voluntary Science Totals to Date: 0 hours (Not included in the above totals or graph)
RSA/NASA Joint Utilization to Date: 0 Hours (not included in the above totals or graph)
ISS Top Program Risk Matrix
Post January 23, 2014 PRAB

Corrective/Preventative Actions
None

Watch Items
No Watch Items Elevated

Continual Improvement
None

Risks (L x C)
Score: 5 x 5
▲ 6352 - Lack of Assured Access to ISS - (OH) - (C,S,T,Sa)
Score: 5 x 4
▲ 6370 - ISS Pension Harmonization - (OH) - (C)
▲ 6344 - ISS Operations Budget Reduction - (OH) - (C)
Score: 4 x 4
▲ 6372 - Full ISS Utilization at 3 Crew - Level 1 - (OZ) - (C,S)
▲ 6169 - Visual Impairment / Intracranial Pressure - (SA) - (C,S,T,Sa)
▲ 6439 - EPROM Memory Leakage - (OD) - (C,S,T,Sa)
Score: 3 x 5
▲ 2810 - Russian Segment (RS) capability to provide adequate MM/OD protection - (OM) - (C,S,T,Sa)
▲ 5688 - ISS Solar Array Management Operations Controls and Constraints - (OM) - (C,S,T,Sa)
▲ 6444 - ISS Cascading Power Failure - (OM) - (C,S,T,Sa)
▲ 6450 - Potential Inability to Support ISS Critical Contingency (and other) EVA Tasks - (XA) - (C,S,T,Sa)
▲ 6382 - Structural Integrity of Solar Array Wing (SAW) Masts due to MMOD Strikes - (OD) - (C,S,T,Sa)
Score: 4 x 3
▲ 5269 - The Big 13 Contingency EVA's - (OB) - (S,T,Sa)
▲ 6438 - C2V2 Comm Unit Vendor Misinterpreting ISS Requirements - (OG) - (C,S,T)
▲ 6452 - Lack of Sufficient Sparing for the Ku-Band Space to Ground Transmitter Receiver Controller (SGTRC) to reach 2020 - (OD) - (C,S,T)
▲ 6420 - NDS Qualification Schedule - (OG) - (C,S,T)
▲ 6408 - FGB Sustaining Contract and FGB spares plan post 2016 undefined - (OB) - (C,S,T,Sa)
Score: 3 x 3
▲ 6039 - Carbon Dioxide Removal Assembly (CDRA) Function - (OB) - (C,T,Sa)
Score: 2 x 2
▲ 5184 - USOS Cargo Resupply Services (CRS) Upmass Shortfall - 2010 through 2016 - (ON) - (S,T)

▲ – Top Program Risk (TPR)

Removed: 6347 - TUBSS, 6032 - On-orbit Stowage, and 6475 - ISS Budget & Schedule

Rescored: 6439, 6039, and 5184
EVA Suit Investigation Status

- Fan pump separator returned from 3011 in December 2013, clogged drums holes, cause of water in the suit issue (silica agglomeration)
- Ion exchange beds additionally returned, completely saturated, and had affinity to silica
  - All suits exposed via numerous ALCLR runs
- New exchange Ion beds developed to clean up water, to be launched on Orb-1
  - Post processing, significant corrosion encountered on ion bed cartridges (noticed during packing 6 days after being processed for flight)
  - JSC Bldg 7 water quality of ion bed processing not up to DI quality water (post test constituents reflected basically Clear Lake City tap water)
- New processes put in place to produce clean Ion exchange beds (charcoal cleansing/rinse, water quality monitored continuously)
  - 2 New beds flown on 38S (late March), 2 more on SpaceX-3, 4 on Orb-2
- Based on water samples returned on 36S (mid March), determination made to flush (3 times) the EMU suits and the airlock water loops, concern is to reduce colloidal silica presently in the loop
  - This is in work, 12L of water to be returned on SpaceX-3 (along with several bad Ion Exchange beds), refill of EMU and Airlock loops using WPA water (significant compatibility testing)
  - Goal is to determine amount of colloidal silica in the water and check for any corrosive effects (low pH) to onboard systems due to contaminated Ion Exchange beds
- New Ion Exchange beds will be incorporated into the loops and then new fan pump separators will be put into suits 3010 and 3005 post water flush (3011 FPS R&R’d in December) – additional FPS to be flown on Orb-2
- New 3003 suit to be flown on SpaceX-3 and suit 3015 returned (sublimator issue)
- Return of hardware and water on SpaceX-3 is key in determining success of water cleanup activity and narrow probable cause to root cause of the initial suit failure
  - Will guide any follow on water cleanup activity
- ISS Program has aggressively been working this issue and close out of EVA MIB report actions prior to declaring readiness for planned EVA capability
External MDM R&R Plans

• On Friday, during normal power up and loading of PPL’s, EXT MDM-2 did not boot properly
  – Power draw was around 35W compared to normal 50 W
  – Numerous re-attempts to bring MDM online unsuccessful, declared failed
  – Spare MDM onboard
  – EXT MDM-1 is healthy and provides complete redundancy to Ext MDM-2 (i.e, no loss of functionality on ISS
  – Next worst case failure team assessed impacts of losing functionality of EXT MDM-1
    • SARJ plan in place to support power loads, docking loads
    • E TCS will continue to operate nominally from lower tiered MDM, TRRJ’s locked in position
    • Additional system configurations made to enhance redundancy (SSRMS hot backup, 2\textsuperscript{nd} S-band string powered up, CMG MDM control switched
    • MT moved to provide access to EXT MDM -2 location on S0
    • Team has good understanding of next worst case failure and concurs with launch and berthing of SpaceX-3 in this configuration
    • Ext MDM was part of Big 13, significant pre-work completed to perform R&R
• Spare MDM to be configured to support R&R
  – Software loads, testing being performed on ground in preps for software load, application of cotherm to box for passive thermal control
• Plans for EVA in work to R&R the EXT-2 MDM
  – NET April 22\textsuperscript{nd}
  – R&R FPS on 3005 (in work today), perform checkouts
  – Continue with flushes of loops and EMUs (to be finished tomorrow)
  – EVA to be conducted with EMUs 3005 and 3011 (Swanson, Mastracchio)
Examples of New Investigations:

- **Vegetable Production System (VEGGIE):** provides the necessary lighting and nutrient delivery for efficient plant growth in space. The plants grown in VEGGIE can support a wide spectrum of uses, from research to education outreach to a fresh food source for astronauts.

- **T-Cell Activation In Aging:** seeks the cause of a depression in the human immune system while in microgravity, which can also help in understanding and treating a range of auto-immune diseases such as arthritis and diabetes, and in inhibiting the natural decline of the immune system as people age.
## Commercial Crew Program: Acquisition

### Commercial Crew Development

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<td>5 Partners: Blue Origin, Boeing, Paragon, Sierra Nevada, ULA</td>
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### Commercial Crew Development Round 2

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### Commercial Crew Integrated Capability

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<td>3 Partners: Boeing, Sierra Nevada, SpaceX</td>
<td>CCiCap</td>
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<td>Scope: Integrated Crew Transportation Systems</td>
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<td>Total Amount Awarded: $1,167M</td>
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### Commercial Crew Transportation Capability

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<tr>
<td>3 Partners: Boeing, Sierra Nevada, SpaceX</td>
<td>CPC (Phase 1)</td>
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<td>Scope: Early Certification Products</td>
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<td>Total Amount Awarded: $29.5M</td>
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<tr>
<td>Partners: TBD</td>
<td>CCtCap (Phase 2)</td>
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<td>Scope: Full Certification Plus Initial ISS Missions</td>
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Certification Strategy

Certification for ISS Crew Transportation

Phase 1
- Alignment with NASA certification requirements
- Eval Team
- Certification Products Contract
- Preliminary Design

Certification to include at least one crewed ISS mission
Verification, validation, test and final certification

Phase 2
- Critical Design
- SEB
- CCtCap - 1 or more awards
- DCR
- FTRR
- ORR
- Certification

*Number of awards to conform to budget

ISS Crew Transportation Services

- ISS Services Contract
- RFP
Objective
Develop and certify a commercial Crew Transportation System (CTS) that can provide safe transportation of NASA crew to the International Space Station as soon as possible, with a goal of no later than 2017. The CTS development will enable the purchase by NASA of commercial services to meet NASA’s station crew transportation needs, once the capability is certified by the agency.

Competition
• Phased acquisition using competitive down-selection procedures
• CCtCap allows for a full and open competition
• Firm fixed-price, performance-based, with fixed-price Indefinite Delivery/Indefinite Quantity (IDIQ) element

Current Status
• Proposals Received Jan. 22, 2014
• CCtCap Award August 2014
Summary

NASA’s Commercial Crew Program is continuing to execute the plans established at the program’s inception in April 2011.

The program is headed into a critical phase during the next year where we will be transitioning into a full-up certification and services contract.
Managing Spaceflight Programs and Projects

7120.5E Overview

Sandra Smalley
Director
Engineering and Program Management Division
Office of the Chief Engineer

April 14, 2014
Program Life Cycle Simplified

<table>
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<tr>
<th>Program Phases</th>
<th>FORMULATION</th>
<th>IMPLEMENTATION</th>
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<tbody>
<tr>
<td>Pre-Program Acquisition</td>
<td>Program Acquisition</td>
<td>Operations</td>
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Key Decision Points

Acquisition Meetings

Major Reviews

I | Acquisition Strategy and Planning Meetings
II | Program System Requirements/ Definition Reviews
III | Preliminary Design Review
IV | Critical Design Review
V | Systems Integration Review

- Operational Readiness Review
- Flight Readiness Review
- Post Launch Assessment Review
- Program Implementation Reviews
Separation of Authorities

Programmatic Authority:
- Mission Directorates
- Programs
- Projects

Institutional Authority:
- Technical Authority:
  - Engineering
  - Safety & Mission Assurance
  - Health & Medical
- Mission Support:
  - Infrastructure
  - IT
  - Financial
  - Procurement
  - Etc.

Programmatic Authority resides with the Mission Directorates and their respective programs and projects.

The Institutional Authority resides with Headquarters and associated Center organizations.
NASA Advisory Council Presentation
Status of Exploration Systems Development

Dan Dumbacher
Deputy Associate Administrator
for Exploration Systems Development
April 15, 2014
Summary

• NASA continues to make great progress with SLS, Orion and GSDO
  – Orion/EFT-1 Crew Module functional testing is complete with Service Module and Launch Abort System assembly complete and ready for integration
  – SLS Core Stage fabrication and assembly facility development in process and test stand construction in work to support core stage/main engines testing
  – GSDO completed PDR in March 2014 and facility/GSE modifications on track to support operations

• SLS, Orion, and GSDO programs remain on track for the first integrated test flight, Exploration Mission-1.
Why Human Space Exploration?

- Scientific and human exploration and pioneering mark advancing civilizations and expand human experience
  - Expands knowledge, fuels innovation, and spurs commerce
  - Requires risk acceptance

- Exploration and pioneering leverages humanity’s powerful motivations:
  - Ignites our imaginations
  - Leads to discovery and science & technical advances
  - Creates a vision of a better future for the next generations

- Space exploration is human and robotic explorers in partnership
  - Robots explore distant and hazardous environments to extend scientific understanding and planning for human missions
  - Human explorers provide greater speed, intuitive ease, and efficiency

- Human space exploration garners national prestige and unites nations around a common goal

Building on our investments in technology, robotic missions, ISS, Commercial Crew, SLS, and Orion, America is poised to lead the next wave of partnerships for international science and human space exploration
Six key strategic principles to provide a sustainable program:

1. Executable with current *budget with modest increases*.

2. Application of *high Technology Readiness Level* (TRL) technologies for near term, while focusing research on technologies to address challenges of future missions.

3. *Near-term mission* opportunities with a defined cadence of compelling missions providing for an incremental buildup of capabilities for more complex missions over time.

4. Opportunities for *US Commercial Business* to further enhance the experience and business base learned from the ISS logistics and crew market.

5. *Multi-use, evolvable* Space Infrastructure.

Global Exploration Roadmap

International Space Station

General Research and Exploration Preparatory Activities

Note: ISS partner agencies have agreed to use the ISS until at least 2020.

Robotic Missions to Discover and Prepare

Mars Sample Return and Precursor Opportunities

Human Missions Beyond Low-Earth Orbit

Explore Near-Earth Asteroid

Extended Duration Crew Missions

Humans to Lunar Surface

Missions to Deep Space and Mars System

Sustainable Human Missions to Mars Surface
Human Exploration Pathways

Mastering the Fundamentals
- Extended Habitation Capability (ISS)
  - High Reliability Life Support
- Deep-space Transportation (SLS and Orion)
- Exploration EVA
- Automated Rendezvous & Docking
- Docking System

Pushing the Boundaries
- Deep Space Operations
  - Deep Space Trajectories
  - Deep Space Radiation Environment
  - Integrated Human/Robotic Vehicle
- Advanced In-Space Propulsion (SEP)
  - Moving Large Objects
- Exploration of Solar System Bodies

Towards Earth Independent
Crewed Orbit of Mars or Phobos/Deimos

Bringing the moon within Earth’s economic sphere.
HUMAN EXPLORATION
NASA's Path to Mars

EARTH RELIANT
MISSION: 6 TO 12 MONTHS
RETURN TO EARTH: HOURS

- Mastering fundamentals aboard the International Space Station
- U.S. companies provide access to low-Earth orbit

PROVING GROUND
MISSION: 1 TO 12 MONTHS
RETURN TO EARTH: DAYS

- Expanding capabilities by visiting an asteroid redirected to a lunar distant retrograde orbit
- Traveling beyond low-Earth orbit with the Space Launch System rocket and Orion spacecraft

MARS READY
MISSION: 2 TO 3 YEARS
RETURN TO EARTH: MONTHS

- Exploring Mars, its moons and other deep space destinations
Evolvable Mars Campaign
A Pathways Approach to Exploration

Earth Dependent
- International Space Station
- Low-Earth Orbit
- Space Launch System

Proving Ground
- Lunar Surface
- Exploration Augmentation Module
- Distant Retrograde Lunar Orbit
- Asteroid Redirect Vehicle
- SEP award

Earth Independent
- Mars Surface
- Mars Vicinity
- MARS VICINITY
- Phobos
- Deimos
- MAVEN
- Mars Cargo Pre-Deployment

The Trade Space
Across the Board
- Solar Electric Propulsion
- In-Situ Resource Utilization (ISRU)
- Robotic Precursors
- Human/Robotic Interactions
- Partnership Coordination
- Exploration and Science Activities

Cis-lunar Trades
- Deep-space testing and autonomous operations
- Extensibility to Mars
- Mars system staging/refurbishment point and trajectory analyses

Mars Vicinity Trades
- Split versus monolithic habitat
- Cargo pre-deployment
- Mars Phobos/Deimos activities
- Entry, descent, and landing concepts
- Transportation technologies/trajectory analyses
HEO Time Phased Capability Prioritization

Mission Classes and Design Reference Missions

Near Term Strategy

HEO MD Objectives and Strategic Knowledge Gaps

Capabilities

Information Captured for Sensitivity Analysis

Investment Priorities to HEOMD Divisions and Programs

Allows:
- Sensitivity analysis on objective satisfaction (asteroid mission, ISS testing, etc.)
- Make / buy / partner options
- Strategic considerations
- Portfolio recommendation
- Data required PPBE for programmatic decision /implementation processes

Partnerships (Commercial, International via GER)
Aspects of the exploration strategy that make it a viable and supportable approach

- Allows for multiple paths to arrive at the same endpoint,
- Pacing changes as budget changes
- Incorporates participation by commercial endeavors and international partners,
- Recognizes different exploration domains depending on the capabilities available
- Multiple types of interesting missions as funding is available
- Shows how capability demonstration missions such as ISS and the asteroid redirect mission fit within the overall desire to establish a human presence in the solar system that will eventually be independent of support from Earth.
- Points out the ultimate objective of exploring and pioneering the solar system, with multiple possible destinations, including Mars.
The NAC endorses NASA’s Human Exploration Strategy as presented by the HEOMD Associate Administrator at the April 16th meeting of the Council. We believe that this approach to Human Exploration provides a roadmap for human exploration programs that will be well received by external stakeholders and the general public.
Areas of Discussion

- Ways to develop understanding, support, and excitement for NASA’s human exploration mission – communication, content (communication strategy for human exploration framework)
- Integration of HEO programs – across directorates, missions, vehicles and systems – progress in implementing the integration process
- Management Processes for NASA programs – would like to do more investigation in this area – must avoid allowing process to take the place of product
- Holding schedule and content, despite uncertain budget environment
- Backup planning for ISS crew transport
- Topics for future discussion, findings or recommendations for the council.
Previous Recommendations Under Discussion

- ISS Extension - closed
- ISS End Of Life Planning – on hold
- NASA Management Instruction 7120 – still gathering data
- Acceleration of Orion’s First Crewed Mission or Increasing Capability of Vehicle Systems - closed

Findings
- Endorsement of Genomics Approach to Biological Research on ISS, and Open Source Data Sharing
- Endorsement of Human Exploration Strategy
Work Plan - July

• Repeating Topics:
  – SLS/Orion status, top risks, sustainability efforts
  – Commercial Crew and Cargo status, top risks, sustainability efforts
  – ISS status, top risks, key research findings
  – Advanced Exploration Systems status, top risks, sustainability efforts

• Special Topics:
  – Commercial interest in space research—bring in several companies to talk about space research and opportunities
  – International Cooperation
  – NASA Guidelines for Program Management
  – Cooperation with Technology and Science Directorates
  – ARM - What will NASA do with the Asteroid once it has been recovered? Before, during, and after the astronaut visit. (Long Term Goals for use of the recovered asteroid – ISRU? First Steps of Propellant Depot? Mining? Manufacturing?)
  – Communicate Plan for Exploration Strategy
Work Plan - September

• Repeating Topics:
  – SLS/Orion status, top risks, sustainability efforts
  – Commercial Crew and Cargo status, top risks, sustainability efforts
  – ISS status, top risks, key research findings
  – Advanced Exploration Systems status, top risks, sustainability efforts

• Special Topics:
  – Technology Roadmaps
  – ISS challenges/ utilization
  – ARM status, risks – commercialization – long term goals for use of the asteroid once recovered