NASA ADVISORY COUNCIL
October 6 - 7, 2010

Exploration Committee Report

Meeting held September 21, 2010

Exploration Committee Members

Mr. Bohdan Bejmuk, *Vice-Chair*

Ms. Nancy Ann Budden

Mr. Joseph Cuzzupoli (absent)

Mr. Richard Kohrs, *Chair*

Dr. John M. Logsdon

Dr. David Longnecker

Gen Lester Lyles

Dr. Bette Siegel (Acting Executive Secretary)

Ms. Jane Parham, Administrative Officer

Fact-Finding Session

- **Discussed status of Human Exploration Framework Team (HEFT)**
  - Phase 1 complete
  - Phase 2 to be completed December 8, 2010
  - Concentration is on a flexible path
- **Discussed ESMD status and budget**
  - Still awaiting Congressional resolution
  - ESMD working options based on most probable outcome – Senate version
  - Transition from Continuing Resolution to final FY2011 budget may not allow time to award contracts and spend 2011 money

Systems Extensibility/Evolution for Other Destinations

HEO/GEO	NEO	Lunar Orbit	Lunar Surface*	Phobos/ Deimos	Mars*
CTV	CTV	CTV + HLL Vx1	CTV + HLL Vx2	CTV + HLLV +xN	CTV + HLLV + xN
HLL Vx1	HLL Vx3				
MMSEV	MMSEV	Rover Cab, Ascent Cab?		MMSEV	Rover Cab, Ascent Cab?
CPS	CPS	CPS	CPSx2	CPSxN	CPSxN
	Transit HAB		Surface Hab	Transit Hab+	Surface Hab, Transit Hab+
	SEP			SEP+, or NEP	NEP

* Additional systems required for these destinations

FACA Meeting Agenda

- **Human Research Program and the Risk Process**
  - Mr. Dennis Grounds, HRP Program Manager
- **Exploration of Near Earth Objects (NEO) Objectives Workshop (Explore NOW)**
  - Dr. John Olson, Director, ESMD Directorate Integration Office
- **Global Point of Departure – Exploration Architecture & Other Agency Partnerships**
  - Dr. John Olson
- **Status of Commercial Crew/Cargo Activity**
  - Mr. Phil McAlister, ESMD Commercial Crew Planning Lead

Human System Risk in Exploration and the Human Research Program

Presented to NAC Exploration Committee
September 21, 2010
by
Dr. Dennis Grounds
Program Manager, Human Research Program

Human System Risks in Exploration Missions –Scoreboard For Risks Requiring Research [p.1 of 2]

Risk	Element	Criticality	
		Lunar	Mars
Risk of Performance Errors Due to Fatigue Resulting from Sleep Loss, Circadian Desynchronization, Extended Wakefulness, and Work Overload	BHP	C	C
Risk of Performance Decrements Due to Inadequate Cooperation, Coordination, Communication, and Psychosocial Adaptation within a Team	BHP	C	A
Risk of Adverse Behavioral Conditions and Psychiatric Disorders	BHP	C	U
Risk of Inability to Adequately Recognize or Treat an Ill or Injured Crewmember	ExMC	A	U
Risk Factor of Inadequate Nutrition	HHC	C	U
Risk of Bone Fracture	HHC	C	C
Risk of Intervertebral Disk Damage	HHC	C	A
Risk of Cardiac Rhythm Problems	HHC	C	A
Risk of Renal Stone Formation	HHC	C	C
Risk of TherapEeutic Failure Due to Ineffectiveness of Medication	HHC	C	A
Risk of Compromised EVA Crew Health and Performance Due to Inadequate EVA Suit Systems	HHC	A	A
Risk of Crew Adverse Health Event Due to Altered Immune Response	HHC	C	A
Risk of Orthostatic Intolerance During Re-Exposure to Gravity	HHC	C	A
Risk of Impaired Control of Spacecraft, Associated Systems and Immediate Vehicle Egress Due to Vestibular/Sensorimotor Alterations Associated with Space Flight	HHC	C	A

Human System Risks in Exploration Missions –Scoreboard For Risks Requiring Research [p.2 of 2]

Risk	Element	Criticality	
		Lunar	Mars
Risk Of Early Onset Osteoporosis Due To Spaceflight	HHC	C	A
Risk of Impaired Performance Due to Reduced Muscle Mass, Strength and Endurance	HHC	A	U
Risk of Reduced Physical Performance Capabilities Due to Reduced Aerobic Capacity	HHC	A	U
Risk of Adverse Health Effects from Lunar Dust Exposure	SHFH	A	n/a
Risk of Adverse Health Effects Due to Alterations in Host-Microorganism Interactions	SHFH	C	A
Risk of Performance Decrement and Crew Illness Due to an Inadequate Food System	SHFH	C	U
Risk of Error Due to Inadequate Information	SHFH	C	A
Risk of Errors Due to Poor Task Design	SHFH	C	A
Risk of Reduced Safety and Efficiency Due to an Inadequately Designed Vehicle, Environment, Tools or Equipment	SHFH	C	A
Risk of Acute and Late Central Nervous System Effects from Radiation Exposure	SR	A	A
Risk of Radiation Carcinogenesis	SR	A	U
Risk of Acute Radiation Syndromes Due to Solar Particle Events (SPEs)	SR	A	A
Risk Of Degenerative Tissue Or Other Health Effects From Radiation Exposure	SR	A	U

Exploration of NEOs Objectives Workshop Summary

Presented to NAC Exploration Committee
September 21, 2010
by
Dr. John Olson
Director, Directorate Integration Office

Identified Primary Technology & Capability Gaps

What technologies and/or capabilities are needed for a human mission to a NEO?

Major capability gaps centered around four primary areas:

1. **Proximity operations - operations for surface and subsurface access**
2. **Characterization – surface/internal target, sample acquisition and handling**
3. **Mission autonomy - autonomy and robustness required for deep space missions**
4. **Human Health Systems - life support and challenges for human health**

Technology development options to address the capability gaps were identified for all of these.

Identified Concepts of Operation

What are the concepts of operations for a human mission to a NEO?

Identified concepts of operations for each mission phases (i.e., LEO & Preparation, In transit to a NEO, At NEO and Earth Return) with focus on operations at a NEO.

Types of Operations at a NEO included -

Category	Operations at a NEO
Human Spacecraft	Field surveys, NEO orbit insertion and station keeping, deployment of exploration vehicle, monitor spacecraft system performance, and exploration vehicle rendezvous and dock with Mothership
EVA	Astronaut EVA to surface from Exploration vehicle
Science	Core sampling and deep drilling, Seismic surveying, Sample collection (bulk and selective) ISRU demos, deployment and emplacement of packages (e.g., seismic sensors, tracking devices)
Robotics	Tele-robotic operations such as Aercam, autonomous drilling, and ISRU testing (prior to EVA, during and after EVA), leaving behind robotic assets

International Space Cooperation and Inter-Agency Partnerships

Presented to NAC Exploration Committee
September 21, 2010
by
Dr. John Olson
Director, Directorate Integration Office

NASA Partnerships: Enabling Exploration

International Activities

- Global Exploration Strategy (GES)
- International Space Exploration Coordination Group (ISECG)
  - 14 Int'l Space Agencies
- Developing the Global Exploration Roadmap
- Bilateral dialogue robotics, analog, ISS utilization, etc
- Strong international participation in analog field tests

Other Government Agencies (OGAs)

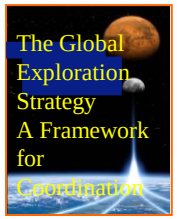
- Leveraging other government programs and technologies to minimize costs & maximize efficiency and innovation (e.g. DoD, DOE, DARPA, NOAA, NSF, DoC)

Science and Academia

- Seeking to maximize synergy between Human Robotic Missions
- Human Research Program
- Coordinating with internal, external groups
- (e.g., NLSI, LSI, LEAG)

Commercial: Traditional & Non-traditional

- Strong NASA interest in enabling commercial opportunities that contribute to exploration program success



International and Inter-Agency Partnerships Strategy

NASA leadership of a sustainable and affordable human space exploration of many destinations is enabled by, and may require, critical international partnerships (IPs)

Purpose:

1. **Reduce costs (not LCC) or obtain funding or resource offsets**
2. **Enhance sustainability thru interdependent alliances, vital contributions, joint/cooperative ventures, and potential critical path dependencies or key contributions**

Build from HEFT – Engage Near-term with IPs for a long-term coordinated vision:

- **Engaging IPs in both bi-lateral and multi-lateral discussions**
- **Communicating human and robotic mission plans/interests in a timely/transparent manner**
- **Sharing US objectives, framework options/decisions, key capabilities list**
- **Leveraging HEFT products for a global exploration roadmap**
- **Shaping technology development, demonstration and precursor investments**
- **Fully utilizing ISS to demonstrate technologies, advanced capabilities, & expanded partnerships**
- **Creating opportunities for new partnerships once timing/environment is "right"**

NASA leadership is considered essential to advance the global exploration strategy

- **Continue to engage via the International Space Exploration Coordination Group (ISECG) and ISS Multilateral Coordination Board (MCB)**
- **HEFT is important to inform and frame the path forward**

Commercial Crew Initiative Overview and Status

Presented to NAC Exploration Committee
September 21, 2010
by
Mr. Philip McAlister
ESMD Commercial Crew Planning Lead

	2011	2012	2013	2014	2015
Commercial Crew	$500	$1,400	$1,400	$1,300	$1,200

The FY 2011 budget request invests $6 billion over five years to spur development of U.S. commercial human spaceflight vehicles.

- **Support potential commercial crew transportation providers to whom NASA could ultimately award a competitive crew transportation services contract.**
- **Important development considerations include human rating existing vehicles, development of capsules that can fly on multiple launch vehicles, and/or developing new high-reliability rocket systems.**

NASA plans to competitively allocate commercial crew funds to support higher and lower risk systems and systems components.

- **NASA will ensure that all commercial systems meet stringent human-rating and safety requirements before we allow any NASA crew member to travel aboard a commercial vehicle.**
- **NASA will work with the private sector to get the broadest range of competitors, from established aerospace companies to emerging companies.**

Objectives and Approach

The objective of the proposed commercial crew initiative is to facilitate the development of a U.S. commercial crew space transportation capability with the goal of achieving safe, reliable, and cost effective access to and from LEO and the ISS. Once the capability is matured and expected to be available to the Government and other customers, NASA could purchase commercial services to meet its ISS crew transportation needs.

Preliminary Approach:

- **Competition through pre-negotiated, milestone-based agreements that support the development, testing, and demonstration of multiple systems.**
- **Support an end-to-end transportation solution that will encourage the development of a range of launch vehicle and spacecraft combinations.**
- **Industry investment capital will be included as part of any agreement.**
- **Clearly and promptly state NASA's safety requirements and ensure that they are met.**
- **Lead to the competitive selection of one or more commercial service providers with the goal of awarding firm fixed price contract(s).**

Insight / Oversight Approach

The insight/oversight approach envisioned will require a change in the way government and industry interact for human spaceflight missions.

- There will be a stronger reliance on the commercial providers to develop a safe, reliable vehicle.
- NASA will have in-depth insight of the vehicle design through NASA personnel who are embedded in the contractor's facility.
- A key facet of certifying the vehicle system will be through the use of requirements and standards. These will be imposed on all the providers and NASA will ensure that these are properly tailored.
- The insight approach should be more efficient, more penetrating, provide more insight and can provide a more reliable system than an approach that embraces the review of contract deliverables and requirements accounting.
- This approach has been highly effective in the past in ensuring reliable high-valued launch vehicle/payloads and robotic spacecraft.

Recommended Action for ESMD – No. 1:

The NAC Exploration Committee requests from NASA EMSD information in the form of three charts: Our intention is to map, illustrate and contrast the high level critical research and technologies that are required for missions to LEO, the Moon, Mars, and NEOs. Intuitively it seems that the critical technologies will increase in number and difficulty as the destinations increase in distance and mission duration.

1) The first chart is already assembled, and was distributed to the Committee September 21, entitled: "Consistent set of Exploration Capability Investments" (Doug Cooke).
2) The second chart maps required critical research and technologies (left axis) against destinations (right hand axis) LEO, Moon, Mars, NEOs.
3) The third chart overlays innovative technologies that may be required or valuable over the same destinations.

Once we have examined and made any changes, we will share these charts with the NAC Technology and Innovation Committee.

Recommended Action for ESMD – No. 2:

RATIONALE:

Dr. Dennis Grounds briefed the NAC Exploration Committee on the risk assessment process that is used by the Human Research Program (HRP) to categorize risks related to human space flight and thus guide future areas of focus for HRP initiatives.

The Committee was pleased with the focus and effort devoted to crew health and safety, and with the depth of engagement of outside experts to assist NASA HRP staff in assessing the risks related to human space flight. The Committee noted that the risks are currently stratified into one of three categories, reflected as Red-Yellow-Green, and they are further stratified relative to design reference missions for Moon and Mars. The Committee finds that further work will be required to guide both the HRP strategic agenda and its timelines. More detail will be required to fully understand the extent of the "gaps" for those risks in the yellow and red categories, and the risks will need to be reevaluated and assessed for new design reference missions (e.g., flights to NEO objects), if such missions receive final approval and budget support

Action to ESMD:

The Committee recommends that the human health risks be further classified by defining the current CRL (countermeasure readiness level) and/or TRL (technology readiness level) associated with each risk, and associating these readiness levels with each risk classification. Such classification will better inform strategic research planning decisions, including both timelines for action and funding priorities. Further, the committee recommends that HRP perform similar risk analyses related to newly identified exploration missions (e.g., NEO), after there is clear definition of NASA's mission strategies and funding priorities.

Recommendation No. 1:

RATIONALE:

The NAC Exploration Committee is pleased with NASA's active engagement in seeking Interagency Partnerships. These efforts are critical in leveraging the innovations, capabilities, and resources necessary to develop the technologies for future space exploration missions.

While excellent communications are taking place at the technical levels amongst government agencies, the Committee feels that these cooperative efforts can be enhanced, and strengthened by gaining support from the top leadership of the appropriate agencies, such as DoD.

RECOMMENDATION:

NASA should seek opportunities to collaborate on technology development with the Space leaders at DoD, the Air Force, and other agencies. In particular, the Administrator should brief the DoD "Partnership Council" [Secretary of the Air Force; Commander of Air Force Space Command; Commander of Strategic Command; and Director of the National Reconnaissance Office] on NASA's technology needs for space exploration and discuss opportunities to co-invest in complementary technology developments that can satisfy the common goals of reliable, affordable access to and through space.

Recommendation No. 2:

RATIONALE:

The June 28, 2010, National Space Policy calls for promoting "appropriate cost- and risk-sharing among participating nations in international partnerships" and augmenting U.S. capabilities "by leveraging existing and planned space capabilities of allies and space partners." The first round of NASA planning for a NEO mission carried out by the Human Exploration Framework Team (HEFT) did not account for potential international participation, but NASA in the second round of HEFT activity that is just beginning intends to factor in potential international contributions. Reversing a NASA policy in place since late 2005, international partners will be able to contribute to the "critical path" in the transportation system required for a NEO mission, in addition to contributions to exploration activities at the NEO. Having significant international contributions may be essential to making NEO and other deep-space missions affordable, given projected NASA budgets over the next 10-15 years. The Exploration Committee is encouraged by the approach set out in the National Space Policy and commends NASA for actively seeking international engagement in exploration planning.

RECOMMENDATION:

The NAC recommends that NASA pursue a policy that, considering the U.S. space industrial base and broad national security interests, invites potential partners to contribute to all aspects of the exploration architecture. In the exceptional case, where appropriate, partnerships on the critical path elements of the deep space transportation system should be considered.

Recommendation No. 3:

RATIONALE:
The future success of a commercial crew Low Earth Orbit (LEO) access vehicle in attracting customers other than NASA will depend in large measure on the recurring cost of operations. NASA is planning to co-fund the development cost and later buy seats on the commercial provider's transportation system. It is in NASA's and commercial provider's interest to drive the cost of operations as low as possible in order to attract other customers and to avoid a scenario where NASA is the only customer able to afford the service. It is therefore of paramount importance to incentivize the commercial developers to design the transportation system with cost of operations sufficiently low to attract other customers in addition to NASA.

RECOMMENDATION:
NASA should develop operability incentives for the acquisition of commercial crew capabilities. These incentives should drive commercial partner design to include features resulting in recurring cost of operations low enough to attract other customers in addition to NASA.

Acronym list

CPS – Cryo Propulsion Stage

CTV – Crew Transfer Vehicle

DARPA- Defense Advanced Research Projects Agency

DOC- Department of Commerce

DoD- Department of Defense

DOE – Department of Energy

GEO- Geosynchronous Earth Orbit

HEO – High Earth Orbit

HLL-Heavy Launch Lift Vehicle

LEAG – Lunar Exploration Advisory Group

LSI – Lunar Science Institute

MMSEV- Multi-mission space Exploration Vehicle

NEO- Near Earth Object

NLSI – NASA Lunar Science Institute

NOAA- National Ocean and atmospheric Administration

NSF – National Science Foundation