NASA ADVISORY COUNCIL
August 5-6, 2010

Exploration Committee

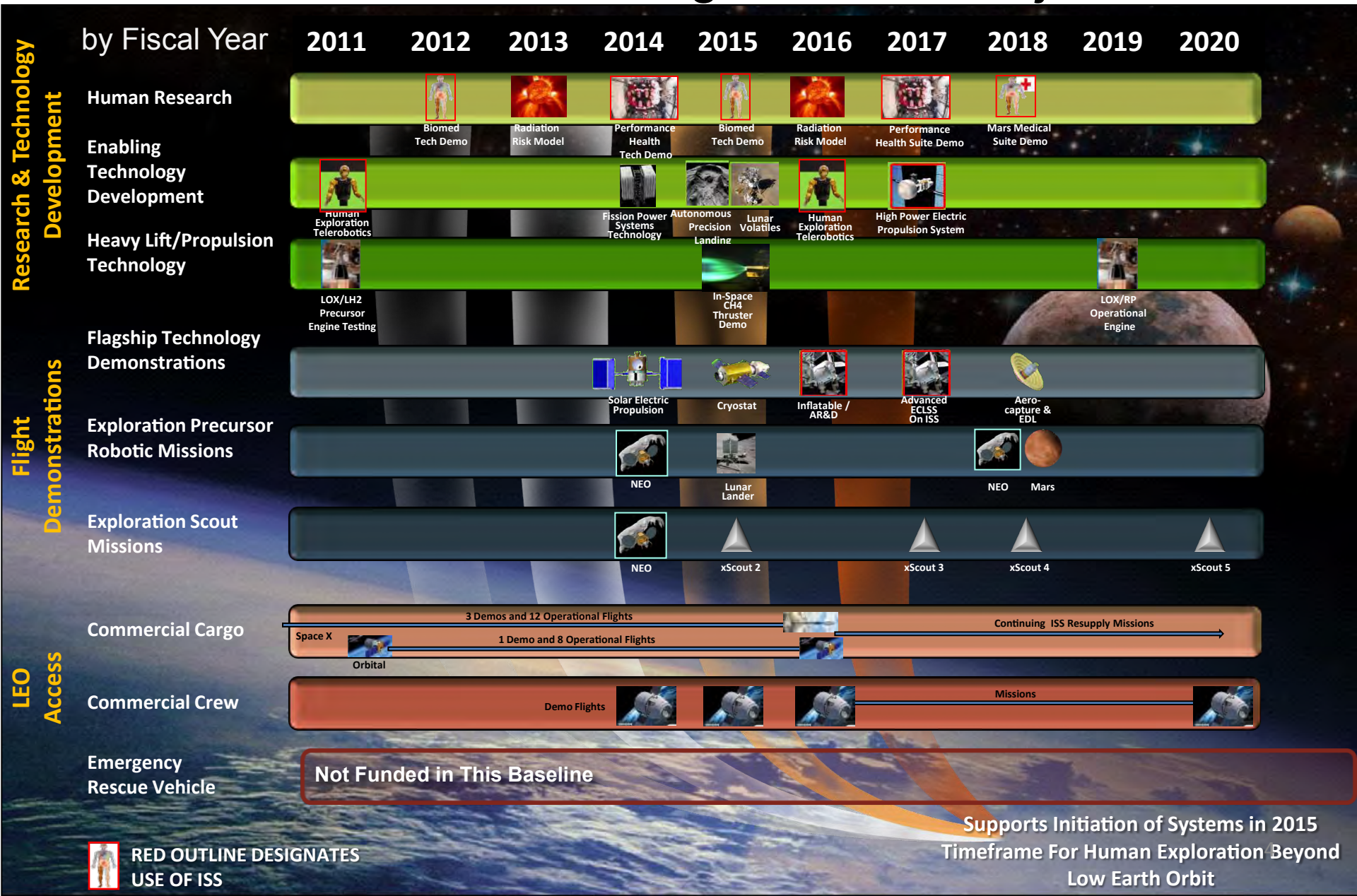
Exploration Committee Members

- Mr. Bohdan Bejmuk
- Ms. Nancy Ann Budden
- Mr. Joseph Cuzzupoli
- Mr. Richard Kohrs, *Chair*
- Dr. John M. Logsdon (absent)
- Dr. David Longnecker
- Gen Lester Lyles (absent)
- Dr. Bette Siegel (Acting Executive Secretary)
- Ms. Jane Parham, Administrative Officer

Exploration Committee Agenda

- Exploration Program Status – Doug Cooke
- Constellation Program Status - Dale Thomas
- Heavy Lift and Propulsion Technology - Cristina Guidi
- Human Research Program Status - Dennis Grounds
- Joint session Exploration /Technology & Innovation Committees:
  - Human Exploration Framework Team (HEFT) - John Olson
  - Cross-cutting Capability Demonstration Missions - Prasun Desai
  - ESMD / OCT Technology Coordination – James Reuther
  - Overview of ESMD New Technology Initiatives - Benjamin Neumann
- International Space Cooperation and Other Partnerships - John Olson

ESMD STATUS
ESMD Planned Programs and Projects



ESMD STATUS
Budget Comparison Chart

	President's Request					Senate Authorization			House Authorization				
	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2011	FY 2012	FY 2013	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
Exploration	4,263	4,577	4,719	4,923	5,179	3,868	5,252	5,264	4,535	4,882	4,889	5,107	5,158
Space Transportation Vehicle	-	-	-	-	-	1,120	1,400	1,400	-	-	-	-	-
Space Launch System	-	-	-	-	-	1,631	2,650	2,640	-	-	-	-	-
House Exploration Program	-	-	-	-	-	-	-	-	4,156	4,517	4,514	4,722	4,733
Technology Demonstration	652	1,262	1,808	2,013	2,087	250	437	449	-	-	5	10	30
Heavy Lift & Propulsion	559	594	597	598	754	-	-	-	-	-	-	-	-
Robotic Precursor Missions	125	506	699	797	923	100	100	100	-	-	5	10	30
Human Research	215	215	215	215	215	155	165	175	215	215	215	215	215
Commercial Cargo	312	-	-	-	-	300			-	-	-	-	-
Commercial Crew	500	1,400	1,400	1,300	1,200	312	500	500	50	50	50	50	50
Commercial Orbital Trans. Demo	-	-	-	-	-	-	-	-	14	-	-	-	-
Commercial Loan/Loan Guar.	-	-	-	-	-	-	-	-	100	100	100	100	100
Constellation Transition	1,900	600	-	-	-	-	-	-	-	-	-	-	-

ESMD STATUS: Challenges

- **Acquisition Planning**
  - Fulfilling guidance of FY11 President's Budget Request will require issuing RFPs early FY11
  - Program offices can not be established until Congress authorizes new initiatives
  - Once PBR approved, there will be a surge of activity to complete program plans, acquisition strategies, and get procurements released
- **Dealing with Continuing Resolution**
  - New programs will remain on hold
  - Direction for Constellation will need to be worked out that keeps critical elements moving forward
- **Constellation Transition**
  - Team completed initial plan for transition
  - Quantifying institutional services that Constellation will no longer cover was discussed at the Human Space Flight Capabilities Forum
  - For future programs to succeed, fixed costs will need to be addressed

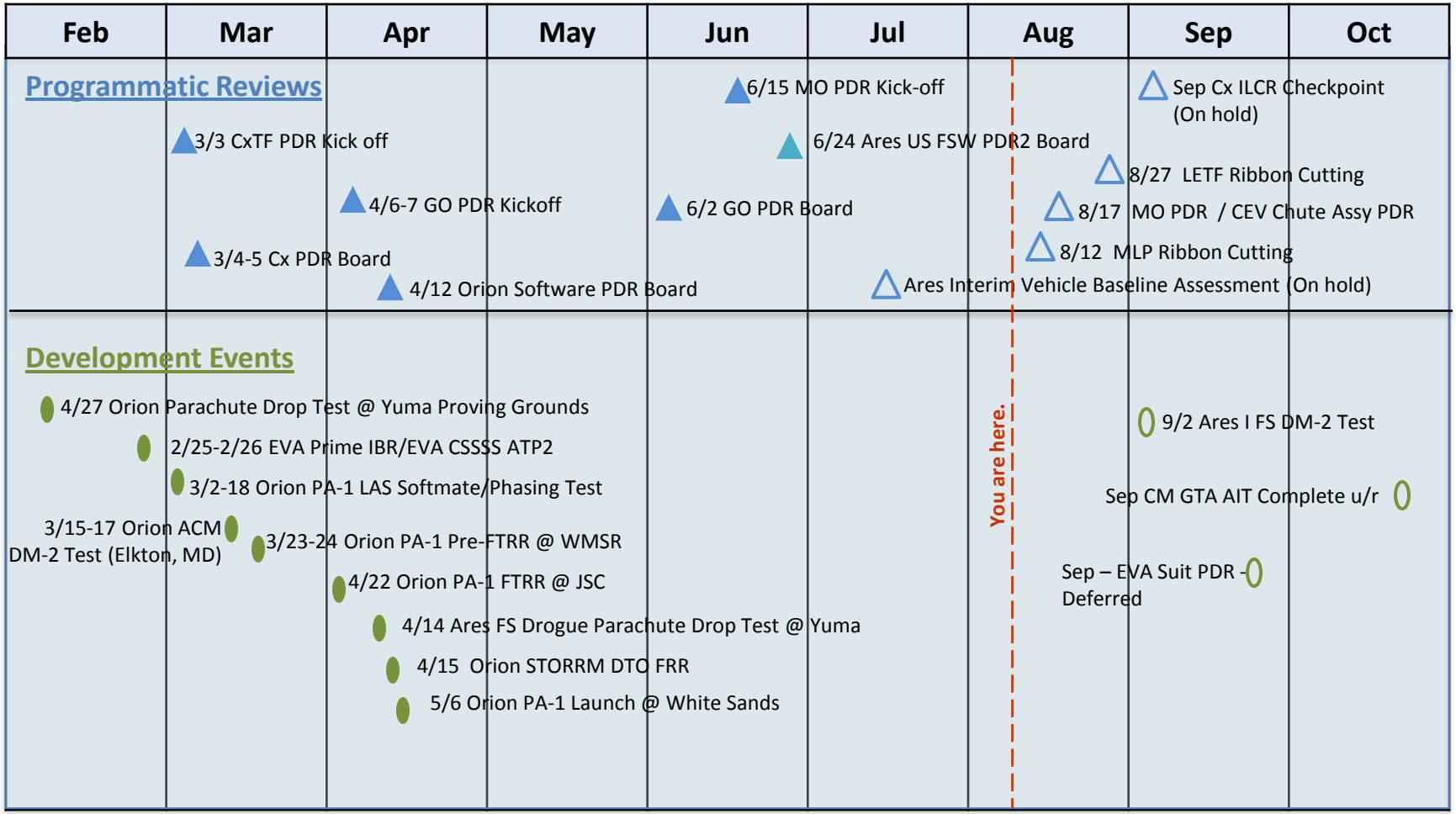
Constellation (Cx) Program Initial Capability PDR

- Cx Program Initial Capability Preliminary Design Review (PDR) completed March 2010 Observations/Results include:
  - The Cx Initial Capability Design is technically sound and able to perform the ISS Mission with acceptable risk and margins
  - CxP exercising risk analysis and management processes as intended to identify, communicate, and mitigate risks early in the design phase
  - Integrated Hazard Analysis process is identifying issues and influencing the Initial Capability design
  - NPR 7120 and 7123 criteria for a Program PDR were satisfied - with the caveat that 7120 cost & schedule criteria still need to be addressed at a future KDP-II
  - Orion and Ares I are well past their Project PDRs and are almost halfway in development towards their Critical Design Reviews (Commit for Production Milestone) scheduled for 2011

Constellation Program

FY10 Planned Events

- FY10 is the "hard" year with the constrained funding profile and achieving Program and Project PDR



ATP – Authority to Proceed
Cx – Constellation
CxTF – Constellation Training Facility
EVA – Extravehicular Activity
FS – First Stage
FSW – Flight Software
GO – Ground Operations
IBR – Integrated Baseline Review
MO – Mission Operations
PDR – Preliminary Design Review
US – Upper Stage

Upcoming Constellation Milestones

- Ares DM-2 test firing, August 2010
- Mobile Launcher completion and ribbon cutting, August 2010
- Ares I-X Flight Test data reduction complete, Summer 2010
- Crew Module tooling complete, September 2010
- Upper Stage MAF construction complete October 2010
- VAB highbay turnover to Cx, February 2011
- 57 facility projects are either complete or under construction
- Continue planned accretion of Shuttle assets
- Orion and Ares I at halfway point towards Critical Design Reviews (a commit for production) scheduled for 2011
- STORRM DTO on STS-134, February 2011

Heavy Lift Program Content

FY 11 President's Budget Request

	2011	2012	2013	2014	2015
Heavy-Lift and Propulsion Technology	$559	$594	$597	$598	$754

- Investigate a broad scope of research and development activities related to space launch propulsion technologies, including:
  - First stage propulsion
  - In-space engine demonstration
  - Foundational propulsion research
- Program goal: provide new National capabilities, reduce costs, and shorten development time for future heavy-lift propulsion systems
- Projects may include commercial, academic and international partnerships

Heavy Lift Near-term Activities

Request for Information (RFI)

- NASA has released an Request for Information (RFI) to engage the aerospace community (Industry, other Government Agencies, and academia)
  - RFI Released: 4 May 2010
  - RFI Responses Due: 21 May 2010
    - Solicit information on current state of technology/capability and end user needs for propulsion systems as well as Program and Business Management

- RFI Metrics
  - 46 Total responses
    - 2 Universities (California State University, Penn State University)
    - 2 General Public
    - 42 Industry (ranging from big hardware providers to component providers and systems analysis firms)

- Overall Observations
  - **Overall Exploration Enterprise:** No consensus - those who were doing want to keep doing, those who were not doing see an opportunity
  - **HLLV Development:**
    - Many asked the question…"What is the 2015 milestone?"
    - Most said start now, don't wait, the whole industry is dying
  - **Fuel Choices on Engines:**
    - Liquid engine companies want to design liquid engines and they will do whatever NASA requests
    - Many engine companies not understanding the Methane direction…no real advocates within the industry
    - Solids company do not agree with direction of solely liquid engine development and prefer a balanced approach (both solids and liquids)

Heavy Lift Near-term Activities

HLLV Broad Agency Announcement (BAA)

- Expanding on previous work via multiple Programs, including recent internal Heavy Lift Launch Vehicle (HLLV) study

- Scope
  - Examine trade space of potential heavy lift launch and space transfer vehicle concepts
    - Launch Vehicles (LOX/RP-based system as baseline and LOX/LH2-based systems)
    - In-space Architecture Elements (space transfer stage, space transfer vehicles, propellant depots, etc)
  - Various propellant combinations for multiple missions objectives
  - Focus is on affordability, operability, reliability, and commonality with multiple end users at the system and subsystem levels
  - Potential Multiple Users: Department of Defense (DoD), commercial, science, international partners, etc.

- Technical Objectives
  - The focus of this study is to determine the technology research and development required for a Heavy Lift System
  - The study shall identify and analyze multiple alternative architectures (expendable, reusable, or some combination) on which a Heavy Lift System addressing the objectives can be based

- Draft BAA Released: 19 May 2010
- Final BAA Released: 29 June 2010
- Proposals Due: 29 July 2010
- Expected Award Date: September 2010

Preliminary Liquid Propulsion Synergies

- Preliminary findings have identified three potential common national engines for launch and in-space propulsion needs
  - RP Engine: 1.0 - 1.25 Mlbf vacuum thrust; ORSC (NASA Acquisition)
  - RL-10 Replacement Engine: ~ 30 Klbf vacuum thrust; Expander Cycle (AF Acquisition)
  - J-2X Class Engine: ~ 280 Klbf (NASA Acquisition)

- These synergies help inform NASA/DoD joint actions to address the liquid rocket engine industrial base

Human Research Program Description

• The Human Research Program (HRP) was formed to focus NASA's research on the highest risk to human health and performance during exploration missions.

•Program goals:

- ❖ Perform research necessary to understand and reduce spaceflight human health and performance risks in support of exploration
- ❖ Develop technologies to reduce medical risks
- ❖ Develop human spaceflight medical standards

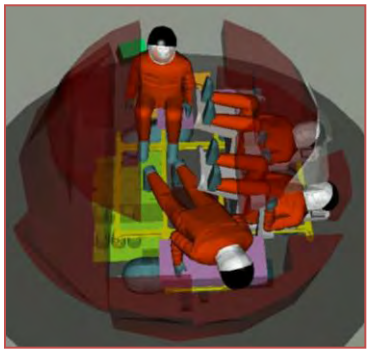
•Products:

- Information to design exploration architectures, vehicles, and missions
- Research deliverables that defines space medical standards

(Medical standards define acceptable human health risk)

- Research support for efficient medical operations

***Example** of a study on the effects of center of gravity on performance*

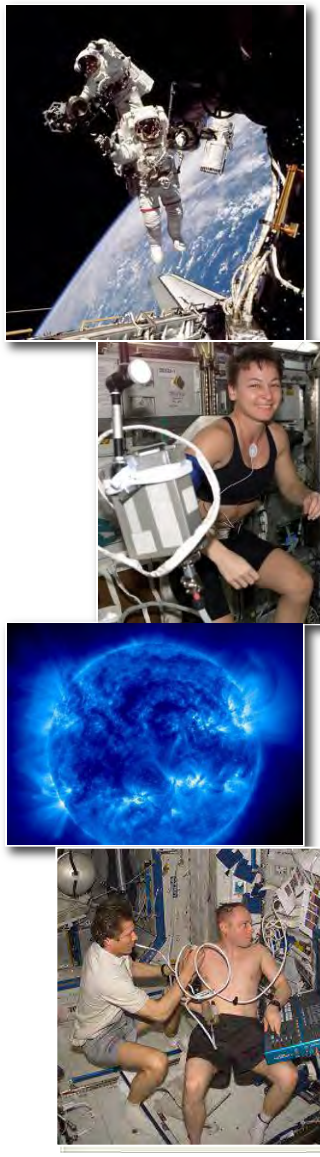


Seat layout for contingency EVA

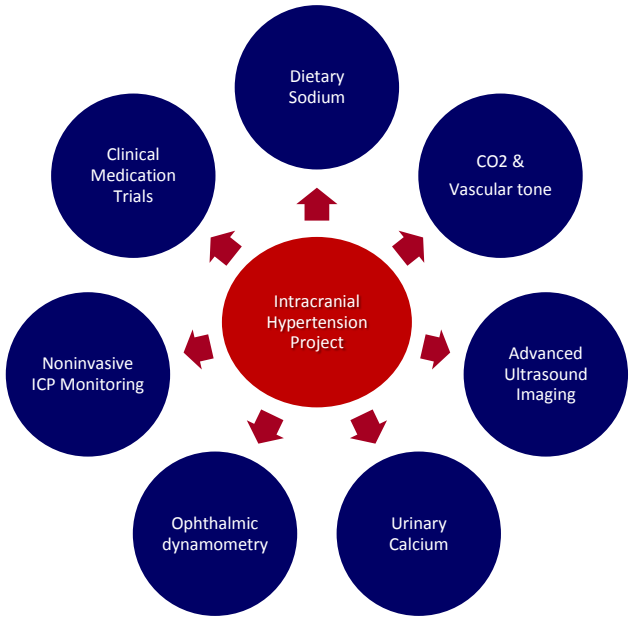
Clay Anderson centrifuges Nutrition blood samples during Increment 15

Human Research Program Content

- Space Radiation
  - Human health effects, limiting factors for vehicle environments and crew selection; computational shielding modeling; measurement and warning technologies
- Exploration Medical Capability
  - Medical care and crew health maintenance technologies (monitoring, diagnostic, treatment tools and techniques); medical data management; probabilistic risk assessment
- Human Health Countermeasures
  - Integrated physiological, pharmacological and nutritional countermeasures suite; Extra-Vehicular Activity (EVA) related physiology research to support new EVA suit development
- Behavioral Health & Performance
  - Behavioral health selection, assessment, and training capabilities; intervention and communication techniques to support exploration missions
- Space Human Factors & Habitability
  - Anthropometry, display/control, usability, cognition, habitability, lighting, ergonomics; advanced food development; lunar dust characterization and toxicological testing
- ISS Medical Project
  - ISS research integration and operations
- NSBRI and Program Science Management
  - National Space Biomedical Research Institute (NSBRI) funding and Program Management and Integration.



Emerging Risk of Intracranial Hypertension with Associated Visual Changes



Background

- Effects observed in 6 ISS long duration crew
- Vision impacts are progressive and not entirely reversible
- Etiology, prevention and treatment options not well understood

What's Needed

- Monitor effects of intracranial pressure in ISS crew
- Perform research to understand etiology
- Develop prevention and treatment options

Approach

In conjunction with Medical Operations

- Assemble team of expertise in the anatomy, physiology, and medicine of intracranial pressure
- HRP will sponsor development of instrumentation in several areas: advanced ultrasound, non-invasive ICP
- HRP will solicit research into etiology in 2010
- Medical Operations will begin routine baseline and in flight measures of opthalmic anatomy using MRI (ground) and ultrasound (flight)
- Develop flight instruments and techniques phased to come on-line as soon as possible

Risk of Intracranial Hypertension with Associated Visual Changes

- **What is the problem?**
  - Optic Disc Edema, Globe Flattening, Choroidal Folds, Hyperopic Shifts and Raised Intracranial Pressure has occurred in Astronauts After Long Duration Space Flight
- **What is the risk?**
  - Given that all astronauts are exposed to microgravity and cephalad fluid shift, and given that both symptomatic and asymptomatic patients have both exhibited optic nerve sheath edema on MRI, there is a high probability that all astronauts have idiopathic intracranial hypertension to some degree, and that those susceptible (via eye architecture, anatomy, narrow disc) have a high likelihood of developing either choroidal folds or papilledema, and that the degree of that edema will determine long-term or permanent vision loss, sequelae, or impairment.

Consequence

The case studies to date have demonstrated a spectrum of severity of symptoms with some cases resolving and others showing no improvement after return to Earth

The concern is that chronic idiopathic intracranial hypertension resulting in treatment resistant papilledema results in permanent and significant decrements in vision

This has been entered as a Top Program Risk For Space & Life Sciences

Likelihood 4 X Consequences; Cost 3, Schedule 1, Technical 4, Safety 4

Human Exploration Framework Team (HEFT) Overview

- Accomplishments since April 2010
  - Organized team, established process, and completed one cycle of the HEFT analysis process
  - Developed nine investment portfolios derived from investment strategies and design reference missions
  - Assessed investment portfolios utilizing Executive Branch Guidance, critical stakeholder interests, and HSF figures of merit
  - Narrowed the trade space and refined design reference missions and budget estimates to fit within future NASA HSF budgets
  - Periodically reported to and received guidance from Steering Council, chaired by ESMD, including SOMD, OCT, OCE, S&MA, IPCE, CMO, and MSD
  - Briefed Administrator and Strategic Management Council
  - Identified next steps

Exploration Committee received process briefing and the Committee will have additional fact-finding discussion with ESMD.

Exploration Research and Development Theme

Theme includes three robust Technology Development and Research Programs:

•Human Research Program

- Conducts space biomedical research critical to crew health and safety

- Enabling Technology Development and Demonstration
  - Develop and demonstrate prototype systems to feed the Flagship, robotic precursor, and other missions of opportunity
  - Shorter duration projects funded at $120 million or less
  - Develop long-range, critical technologies to provide the foundation for a broad set of future exploration capabilities
  - Provide infusion path for promising, game-changing technologies developed by Space Technology Program

•Flagship Technology Demonstrations

- In-space demonstrations with high potential to demonstrate new exploration capabilities
- Projects funded at $400 million to $1.0 billion over less than five years

Enabling Technology Development and Demonstrations
2011 – 2020 Timeframe

- Proposed Demonstrations
  - Lunar Volatiles Flight Experiment: Flight demonstration with xScout; verify presence of water and other volatiles on the Moon by direct in-situ measurements of the lunar regolith
  - High-Power Electric Propulsion Systems Test : Ground demonstration; design, build, and test complete, sub-scale electric propulsion system scalable to power levels (>100 kW)
  - Autonomous Precision Landing & Hazard Avoidance: Ground Demonstration; test an integrated autonomous landing and hazard avoidance system consisting of imaging sensors and navigation and control algorithms
  - Human Exploration Telerobotics: Flight demonstration on ISS; enable safe and cooperative interactions between humans and robots by demonstrating teleoperation of multiple robots on the ground from on-orbit, and control of complex on-orbit robots from the ground
  - Fission Power Systems Technology: Ground demonstration; test power conversion and thermal management technologies for a 40 kW fission power system (test system uses non-nuclear heat source)

Flagship Technology Demonstrations (FTD)
2011 – 2020 Timeframe

- Proposed Missions
  - Solar Electric Propulsion (SEP): Deliver revolutionary benefits by combining advanced space propulsion with efficient, lightweight, array technology.
  - Cryogenic Storage and Transfer: Mission would demonstrate key technologies required for the development of cryogenic propellant storage and transfer, thus supporting exploration beyond Low Earth Orbit.
  - Inflatable ISS Mission Module: Advance, demonstrate and integrate technologies needed for lightweight/inflatable modules, and AR&D delivery capabilities.
  - Advanced environmental control and life support: Demonstrate integration of advanced technology systems for a closed loop (95%) environmental control and life support (ECLS), waste management to reduced logistics materials.
  - Mars-Based Aero-assist Demonstration: Demonstrate, at Mars, advanced aero-capture and large mass delivery entry descent and landing (EDL) technologies using an instrumented flight technology demonstration system.
- First two missions begin development in FY11 using existing civil service and contractor workforce

International Partnerships Strategy

- **NASA leadership of a sustainable and affordable human space exploration of many destinations is enabled by, and may require, critical <u>international partnerships (IPs)</u>**
- **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 with 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 HEFT-derived 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

Exploration Committee Observation 1

We note that there is currently no budget or roadmap for space exploration agreed to by the White House, Congress, and NASA leadership. This complicates ESMD operations.

Exploration Committee Observation 2

If NASA selects LOX-Kerosene combination of propellants for Heavy Lift Launch Vehicle first stage, the following two considerations should be kept in mind:

- Russia currently leads LOX-Kerosene propulsion technology.

- LOX-Kerosene will provide NASA with an opportunity to create a huge operability improvement by using high pressure kerosene as the working fluid in the Thrust Vector Control actuation system, thus eliminating the need for hydraulic power generating system.

  This approach has been successfully used in Russian RD-170 1500K lbs thrust Lox-Kerosene engine resulting in simpler and lower weight engine/TVC system, much easier to operate. In order to benefit from this approach the engine and its TVC should be designed as an integrated system. Outcome of this design decision will not only be a lighter, less expensive to operate propulsion/TVC system, but a “green” stage with complete absence of toxic reactants and conventional hydraulic fluid.

Exploration and Innovation & Technology Committees Finding

(p.1 of 2)

The NAC Subcommittees met as a joint session at JPL on August 4, 2010, to discuss issues that concern and intersect our respective subcommittees.

Uncertainties and lack of budget consensus complicate efforts to define, fund, and promote requirements for space technology. The Office of Chief Technologist is charged in part to address future technology development within NASA. ESMD has funding for Technology development and demonstrations.

We observe that the recently established Office of Chief Technologist has made significant and positive advances in identifying advanced technologies required for future human and robotic exploration of space. They have moved forward quickly and aggressively with plans and an organization to rapidly facilitate technologies that will be required for a variety of future missions to the Moon, Mars, or a Near Earth Object (NEO).

Exploration and Innovation & Technology Committees Finding

(p.2 of 2)

We support and applaud the direction of Office of Chief Technologist for maintaining close communications and interactions with the ESMD, coordinating critical-path technologies and technology development required to execute a roadmap to future human exploration beyond low earth orbit (LEO). Because future technologies represent an area of overlap between OCT and ESMD, these interactions are critical to avoid duplication, cross purposes, and gaps, and may result in schedule and cost savings, and position NASA to more effectively execute a future space exploration effort.

We encourage continued collaboration and request a future update on coordination within the NASA Office of Chief Technologist and ESMD.