Overview

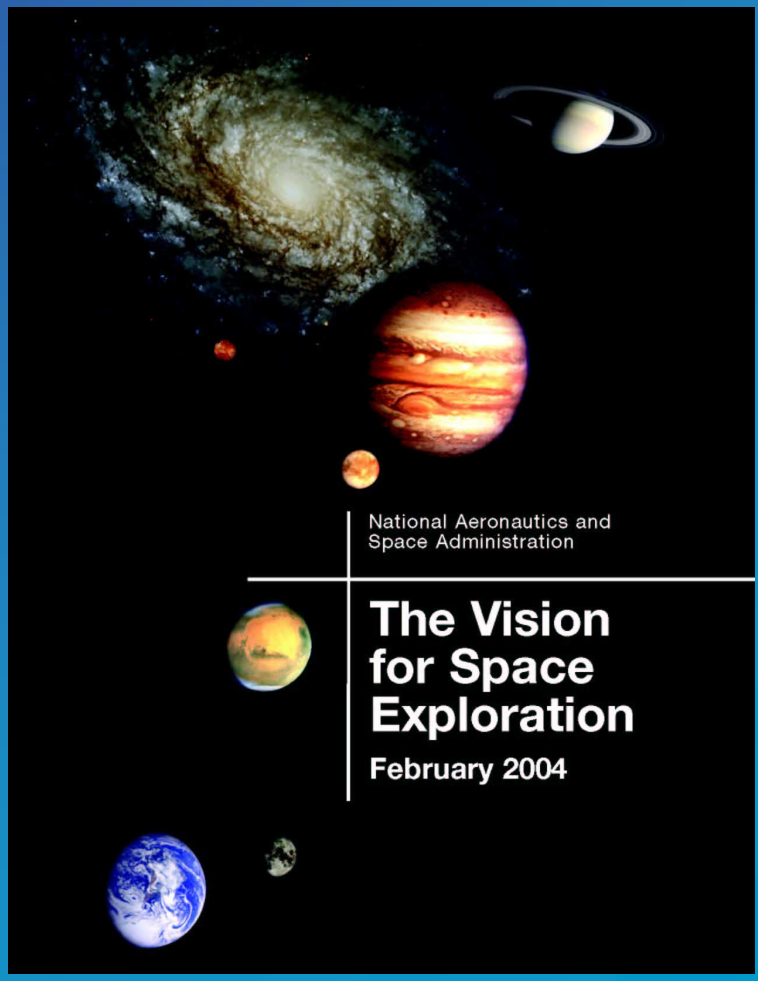
Transitioning to The Vision for Space Exploration

June 2004

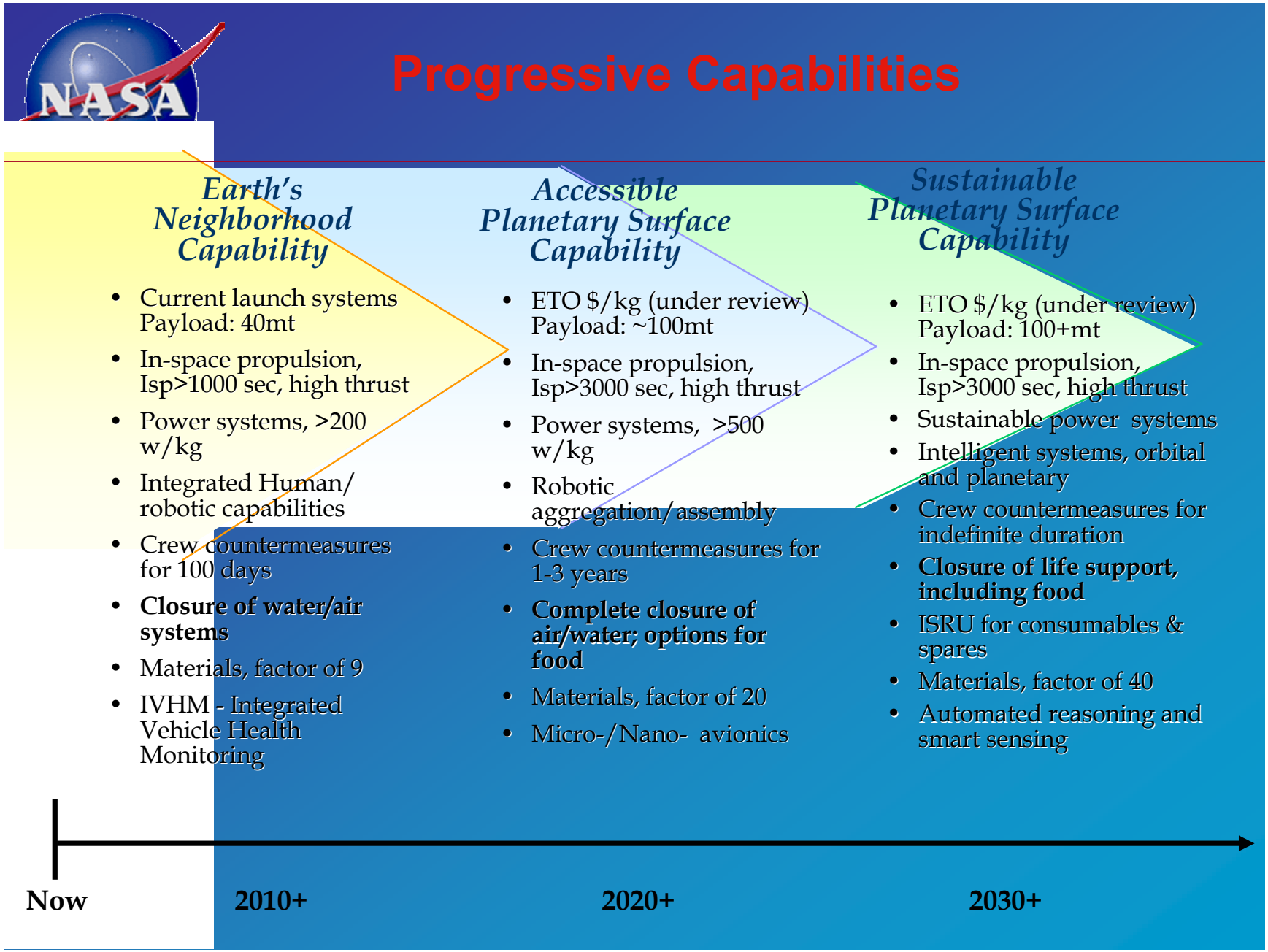
Strategic Directives Guiding the Human Support Technology Program

- Vision for Space Exploration (February 2004)
- President's Commission on Implementation of the United States Space Exploration Policy Report:"*A Journey to Inspire, Innovate,and Discover*"

  (June 2004)




NASA
"The Commission finds that successful development of identified enabling technologies will be critical to the attainment of exploration objectives within reasonable schedules and affordable costs"


Progressive Capabilities
Earth's Neighborhood Capability
• Current launch systems Payload: 40mt
• In-space propulsion, Isp>1000 sec, high thrust
• Power systems, >200 w/kg
• Integrated Human/ robotic capabilities
• Crew countermeasures for 100 days
• Closure of water/air systems
• Materials, factor of 9
• IVHM - Integrated Vehicle Health Monitoring
Accessible Planetary Surface Capability
• ETO $/kg (under review) Payload: ~100mt
• In-space propulsion, Isp>3000 sec, high thrust
• Power systems, >500 w/kg
• Robotic aggregation/assembly
• Crew countermeasures for 1-3 years
• Complete closure of air/water; options for food
• Materials, factor of 20
• Micro-/Nano- avionics
Sustainable Planetary Surface Capability
• ETO $/kg (under review) Payload: 100+mt
• In-space propulsion, Isp>3000 sec, high thrust
• Sustainable power systems
• Intelligent systems, orbital and planetary
• Crew countermeasures for indefinite duration
• Closure of life support, including food
• ISRU for consumables & spares
• Materials, factor of 40
• Automated reasoning and smart sensing
Now
2010+
2020+
2030+

A Journey to Inspire, Innovate, and Discover

- The Commission identified 17 areas for initial focus. Among them are :
  - *Advanced Power and Propulsion*
  - *Cryogenic fluid management*
  - *Closed-loop life support and Habitability*
  - *Extravehicular activity systems*
  - *Scientific data collection and analysis*
  - *Planetary in-situ resource utilization*

Risk Mitigation Status
Technology Readiness Level (TRL)
and Countermeasures Readiness Level (CRL)

TRL Definition	TRL/CRL Score	CRL Definition	CRL category	
Basic principles observed	1	Phenomenon observed and reported Problem defined	Basic research	
Technology concept and/or application formulated	2	Hypothesis formed, preliminary studies to define parameters. Demonstrate feasibility		
Analytical and experimental critical function/proof-of-concept	3	Validated hypothesis. Understanding of scientific processes underlying problem		Research to prove feasibility
Component and/or breadboard validation in lab	4	Formulation of countermeasures concept based on understanding of phenomenon	Counter-measure develop-ment	
Component and/or breadboard in relevant environment	5	Proof of concept testing and initial demonstration of feasibility and efficacy		
System/subsystem model or prototype demonstration in relevant environment	6	Laboratory/clinical testing of potential countermeasure in subjects to demonstrate efficacy of concept		
Subsystem prototype in a space environment	7	Evaluation with human subjects in controlled laboratory simulating operational space flight environment		Counter-measure demonstration
System completed and flight qualified through demonstration	8	Validation with human subjects in actual operational space flight to demonstrate efficacy and operational feasibility		
System flight proven through mission operations	9	Countermeasure fully flight-tested and ready for implementation	Countermeasure operations	

Biological And Physical Research Enterprise Aligning With The Vision For U.S. Space Exploration

- Refining Bioastronautics "Critical Path Roadmap (CPR)" in light of recently established and configuration controlled Level 0 Exploration Requirements/Level 1 Objectives http://research.hq.nasa.gov/code_u/bcpr/index.cfm
  - Roadmap initiated in 1997 -- focuses research and technology solutions on:
    - Reduction or elimination of identified risks to humans during space flight
    - Increased efficiencies of systems supporting humans in space
  - Current activities:
    - Assessed risks in light of Vision for U.S. Space Exploration
      - Under independent review by National Research Council (joint review by Institute of Medicine, Space Studies Board and Aerospace Engineering Board)
      - Updated CPR publicly released for comment, consolidated comments to be provided to NRC
    - Reassessing countermeasure validation requirements and strategy
      - Joint Bioastronautics/Fundamental Space Biology workshop held April 13-15 to determine appropriate animal models.
      - Human Subjects Strategy Workshop, May 12-13, JSC
      - Review with Astronaut Office and Flight Surgeons, May 25-26, JSC
      - Results to be incorporated as appendix to CPR, subjected to the NRC (IOM/SSB/ASEB) review

Critical Path Roadmap Reference Missions

Design Reference Mission	1 Year ISS	Lunar	Mars
Crew Size	2 +	4 – 6	6
Launch Date	2005?	NET 2015, NLT 2020	NET 2025 – 2030
Mission Duration	12 months	10 – 44 days	30 months
Outbound Transit	2 days	3 – 7 days	4 – 6 months
On-Site Duration	12 months	4 – 30 days	18 months
Return Transit	2 days	3 – 7 days	4 – 6 months
Communication lag time	0+	1.3 seconds +	3 – 20 minutes +
G-Transitions (assumes no artificial g)	2	4	4
Hypogravity	0 g	1/6g for up to 30 days	1/3 g for up to 18 months
Internal Environment	~ 14.7 psi	TBD	TBD
EVA	0 – 4 per mission	2 – 3/week; 4 – 15/person	2 – 3/week; 180/person

Rating Risks

- Stoplight format adopted as a communication and decision-making tool:
  - R/Y/G rating used to communicate relative priorities and to guide decisions about research program resource allocation

Criteria for Assigning Red/Yellow/Green Risk Rating

Risk Rating	Human Health Risk	System Performance/Efficiency Risk
Red	Unacceptable risk of serious adverse health or performance consequences; there is no mitigation strategy that has been validated in space or demonstrated on Earth.	Considerable potential for improvement in mitigation efficiency in many areas; proposed missions may be infeasible without improvements.
Yellow	High risk of serious health or performance consequences; there is no mitigation strategy that has been validated in space.	Considerable potential for improvement in mitigation efficiency in a few areas.
Green	Health and performance consequences are known or suspected, but will not affect mission success due to effective mitigation strategies that have been validated in space.	Minimum or limited potential for improvement in mitigation efficiency.

Current Critical Path Roadmap (Draft) Rating Risks: Human Health

R	Unacceptable risk of serious adverse health or performance consequences; there is no mitigation strategy that has been validated in space or demonstrated on earth.
Y	High risk of serious health or performance consequences; there is no mitigation strategy that has been validated in space.
G	Health and performance consequences are known or suspected, but will not affect mission success due to effective mitigation strategies that have been validated in space.

RISK #	Theme	Discipline	Risk Category	ISS (1yr)	Moon (30d)	Mars (30m)
1	HH&C	Bone	Accelerated Bone Loss and Fracture Risk	Y	G	Y
2	HH&C	Bone	Impaired Fracture Healing	G	G	R
3	HH&C	Bone	Injury to Joints and Intervertebral Structures	Y	Y	Y
4	HH&C	Bone	Renal Stone Formation	G	G	G
5	HH&C	Cardio	Occurrence of Serious Cardiovascular Dysrhythmias	Y	Y	Y
6	HH&C	Cardio	Diminished Cardiac and Vascular Function	Y	Y	Y
7	HH&C	Env Health	Define Acceptable Limits for Contaminants in Air and Water	G	Y	R
8	HH&C	IIH	Immunodeficiency / Infection	Y	Y	Y
9	HH&C	IIH	Virus-Induced Lymphomas and Leukemia's	Y	G	Y
10	HH&C	IIH	Anemia, Blood Replacement & Marrow Failure	G	Y	Y
11	HH&C	IIH	Altered Host-Microbial Interactions	G	G	Y
12	HH&C	IIH	Allergies and Autoimmune Diseases	G	G	Y
13	HH&C	Muscle	Skeletal Muscle Atrophy Resulting in Reduced Strength and Endurance	G	G	Y
14	HH&C	Muscle	Increased Susceptibility to Muscle Damage	G	G	Y
15	HH&C	Neuro	Vertigo, Spatial Disorientation and Perceptual Illusions	Y	Y	Y
16	HH&C	Neuro	Impaired Movement Coordination Following G-Transitions	Y	Y	Y
17	HH&C	Neuro	Motion Sickness	G	G	G
18	HH&C	Nutrition	Inadequate Nutritional Requirements	G	G	Y
19	AMC	Clin	Monitoring & Prevention	Y	Y	R
20	AMC	Clin	Major Illness & Trauma	Y	R	R
21	AMC	Clin	Pharmacology of Space Medicine Delivery	Y	Y	R
22	AMC	Clin	Ambulatory Care	G	G	Y
23	AMC	Clin	Return to Gravity/Rehabilitation	G	Y	R
24	AMC	Clin	Insufficient Data/Information/Knowledge Management & Communication	G	Y	R
25	AMC	Clin	Skill Determination and Training	G	Y	R
26	AMC	Clin	Palliative, Mortem, and Post-Mortem Medical Activities	Y	R	R
27	BH&P	HBP	Human Performance Failure Due to Poor Psychosocial Adaptation	R	Y	R
28	BH&P	HBP	Human Performance Failure Due to Neurobehavioral Problems	R	Y	R
29	BH&P	SHFE	Mismatch between Crew Cognitive Capabilities and Task Demands	Y	Y	R
30	BH&P	HBP	Human Performance Failure Due to Sleep Loss and Circadian Rhythm	G	G	Y
31	RH	Rad	Carcinogenesis	Y	R	R
32	RH	Rad	Acute and Late CNS Risks	Y	Y	R
33	RH	Rad	Other Degenerative Tissue Risks	Y	Y	R
34	RH	Rad	Heredity, Fertility and Sterility Risks	G	G	Y
35	RH	Rad	Acute Radiation Syndromes	G	R	R

Current Critical Path Roadmap (Draft) Rating Risks: System Performance/Efficiency

	AHST Risk Rating Criteria for System Performance Risks	
Rating		
R	Considerable potential for improvement in efficiency in many areas, or proposed missions may be infeasible without improvements.	
Y	Considerable potential for improvement in efficiency in a few areas	
G	Minimum or limited potential for improvement in efficiency.	

RISK NUMBER	Theme	Discipline	Risk Category	ISS (1yr)	Moon (30d)	Mars (30m)
36	AHST	AEMC	Monitor Air Quality	Y	R	R
37	AHST	AEMC	Monitor External Environment	Y	R	R
38	AHST	AEMC	Monitor Water Quality	Y	R	R
39	AHST	AEMC	Monitor Surfaces, Food and Soil	Y	R	R
40	AHST	AEMC	Provide Integrated Autonomous Control of Life Support Systems	G	Y	R
41	AHST	AEVA	Provide Space Suits and Portable Life Support Systems	G	Y	R
42	AHST	AFT	Maintain Food Quantity and Quality	Y	G	R
43	AHST	ALS	Maintain Acceptable Atmosphere	G	Y	R
44	AHST	ALS	Maintain Thermal Balance in Habitable Areas	G	Y	R
45	AHST	ALS	Manage Waste	G	Y	R
46	AHST	ALS	Provide and Maintain Bioregenerative Life Support Systems	G	Y	R
47	AHST	ALS	Provide and Recover Potable Water	G	Y	R
48	AHST	AHST	Inadequate Mission Resources for the Human System	Y	R	R
49	AHST	SHFE	Mismatch between Crew Physical Capabilities and Task Demands	G	Y	R
50	AHST	SHFE	Mis-assignment of Responsibilities within Multi-agent Systems	Y	Y	R

Biological And Physical Research Enterprise Efforts to Align With Vision For U.S. Space Exploration

- Developing medical operating bands within which level of risk can be accepted for Moon/Mars
  - Initiated by NASA Chief Medical Officer
  - Focused NASA/National Space Biomedical Research Institute team assessing currently accepted risk levels (target completion June)
  - Will be subjected to external review
- Examining current Enterprise research portfolio to determine degree of alignment with Vision
  - Determining specific product lines (countermeasures, technologies, research results) and developing associated work breakdown structures
    - Aligned with Critical Path Roadmap
- Evaluating mechanisms to stabilize funding to external research community
  - Alternative approaches to soliciting research, including increased focus in product line areas of interest, higher funding levels per effort, increased emphasis on teaming
  - Working with Biological and Physical Research Advisory Committee to consider methods for employing ground based research and flight opportunities in combination so as to streamline process and provide greater funding stability for research community.

Aligning with the Vision: Exploration Research Areas of Emphasis

- Research areas of emphasis include:
  - Human Health and Countermeasures Research – predominant areas of emphasis include:
    - Radiation health effects
    - Loss of bone density and muscle strength
    - Behavioral health
    - Trauma (injury and illness)
  - Technology development – predominant areas of emphasis include:
    - Real-time medical diagnosis and treatment
    - Human habitability technologies
      - Life support systems
      - Environmental safety
      - Nutrition
      - Machine-human interfaces
  - Research which supports the development of lower mass, lower volume, more efficient and reliable exploration systems
- Recognized need to:
  - Maintain a fundamental research base to seed future endeavors
  - Continue to deliver and communicate Earth benefits of space research

Code U Efforts To Align With The Vision For U.S. Space Exploration

- Through FY06 budget development effort, we will adjust research portfolio to meet exploration agenda
- Working closely with the Office of Space Flight and the International Space Station Program to adjust research manifest
  - Considering employing free flying spacecraft to complement on-going ISS research activities

Summary

- Code U is aggressively aligning its efforts to support the Vision for U.S. Space Exploration
  - Refining Bioastronautics “Critical Path Roadmap”
    - Defining accepted risk criteria and developing medical operating bands within which the level of risk can be accepted for Moon/Mars (initiated by the Agency Chief Medical Officer)
    - Countermeasure Validation Requirements and Strategy development
      - Informs crew size/increment duration
  - Examining Enterprise research portfolio to determine degree of alignment with Vision
    - Adjusting research portfolio and developing ‘product line’ framework to meet Vision needs
  - Considering alternative approaches for engaging the research community
  - Establishing relationships with other Enterprises
  - Working closely with the Office of Space flight to address associated requirements for the International Space Station

Backup

Types of Critical Path Roadmap Risks

- A risk is the conditional probability of an adverse event occurring or a system-related inefficiency
  - Human health and medical risks arise from exposure to the hazardous conditions of space flight (e.g., microgravity, radiation, confinement)
    - Thirty-five risks classified as human health or medical
  - System performance and efficiency risks involve the technologies required for providing a safe and habitable environment
    - Fifteen risks classified as system performance and efficiency-related
- Different criteria employed to assess and rate the risks
  - Human health and medical risks use traditional risk assessment criteria of estimated likelihood of a risk's occurrence and its severity of impact on crew health or performance, should the risk occur
  - System performance and efficiency risks use a rating scheme based on improved efficiency
  - Both types use risk mitigation status (readiness levels)

ISS – Human Support Systems Research, Development, and Demonstration

- Examples of Specific Products or Projects on the ISS:
  - Performance/reliability testing of a Sabatier reactor (to recycle CO2, and diminish need for resupply for ISS crew – informs closed loop life support for Moon/Mars) – may transition from RD&D into operations during ISS lifetime [Node 3 already scarred]
  - Validation of system stability and new design tools for low mass, reduced gravity performance of thermal control subsystems and components -- primarily for advanced life support and with additional applicability to nuclear propulsion thermal control [requires FIR]
    - Examples: phase separators, passive thermal loops, evaporation/condensation systems for heating and cooling systems of lesser mass than now used
  - Characterization of flammability and smoke from spacecraft materials in candidate atmospheres (reduced pressure, enriched oxygen concentration) for Moon and Mars [requires CIR]
    - Examples: 0g testing of polyethylene, plastics, and other materials; will verify a new test method(s) in 1g for materials' selection
  - Characterization and verification of performance of onboard and advanced smoke detectors and suppression systems [requires CIR]
    - Examples: False smoke alarm on ISS today occurs; first test of CO2 suppression system

ISS – Human Support Systems Research, Development, and Demonstration

- Examples of Specific Products or Projects on the ISS (continued):
  - Experimental demonstration of rapid prototyping technology for in-space fabrication of spare parts or fabrication / recycling of medical instruments [requires MSRR]
  - Experimental demonstration of granular media for guidance for particulate control during EVA surface operations and for materials' handing for ISRU [requires FIR]
  - Demonstration of microbial technologies for water recycling methods for advanced ECLSS [location TBD – either FIR or Express Rack]
  - Demonstration of new technologies for oxygen generation [location: TBD, likely Express Rack]
  - Demonstration of 0g fabrication of useful materials from regolith simulants [requires SpaceDrums]
- The range of products have associated requests for ISS resources
  - Capacity to meet requests dependent upon several factors -- Shuttle Return to Flight requirements, ISS vehicle health and maintenance needs, post-Shuttle vehicle capabilities, etc.
  - Actively working with the Office of Space Flight to identify ways to address requirements in light of available capacity