Human Research for Space Exploration

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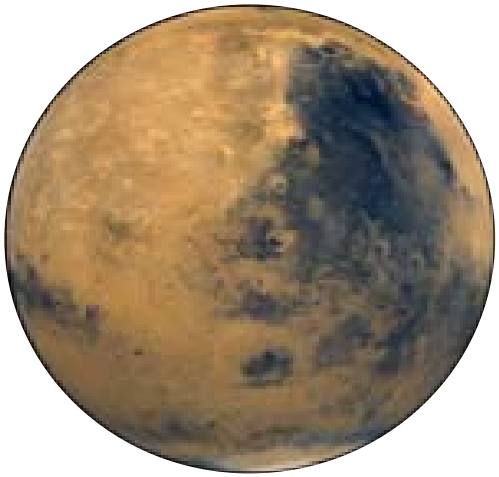
Vision for Space Exploration…. to Mars and Beyond



The human element is the most complex element of the mission design

Mars missions will pose significant physiological and psychological challenges to crew members

Human engineering, human robotic/machine interface, and life support issues are critical

Bioastronautics Research Roadmap identifies risks to human health in space and in planetary environments

The ISS and the Moon must be used to investigate exploration risks to the "Go/No Go" decision

Ground-based and flight research will provide the knowledge and technology to mitigate the risks to human health during and after space exploration

Human Research Program Goals

- Reduce spaceflight risks to humans, focused on the highest risks to crew health and performance during exploration missions
- Enable development of human spaceflight medical and human factors standards
- Development and validation of technologies that serve to reduce medical risks associated with human spaceflight.

Bioastronautics Roadmap

- The Bioastronautics Roadmap is the framework for identifying, assessing, and reducing the risks of crew exposure to the hazardous environments of space.
- The Roadmap provides information for making informed decisions about determining research priorities.
- The Roadmap defines processes for accommodating new information and technology development as it becomes known, and guides the prioritized research and technology development that, coupled with operational space medicine, will inform:

    1. Development of medical standards
    2. Requirements for the human system
    3. Implementation of medical operations

‘Standards to Deliverables’

- NASA has defined a “standards to deliverables” risk mitigation approach for exploration.
- Crew health and performance standards will be defined by the NASA Chief Health and Medical Officer to set acceptable risk for exploration missions.
- These standards will define the need for deliverables that allow crew health to be maintained within acceptable limits based on the levels of care required for the mission scenario.
- The role of the HRP is to conduct research and develop technology that underlies standards development as well as enables deliverables which ensure that standards can be met.

Managing Human Health Risks

- **Bioastronautics Roadmap**
  - Lists 45 major risks to human health in space exploration
  - >450 associated “Research & Technology Questions” (R&TQs)
  - Reviewed and approved by the Institute of Medicine (IOM)
- **Standards to deliverables approach**
  - Establish 8 standards for human health
  - Use the standards to prioritize risks, focus research, and set deliverables aligned with the exploration schedules
- **Risk Management Analysis Tool**
  - The Risk Mitigation Analysis Tool (RMAT) has been proposed as an analytical and communication tool to be used to compare standards and requirements against known mission architectures and resources.
  - The RMAT collects the appropriate standard, program requirements, and research and technology requirements that result in deliverables per architecture to mitigate the highest priority human risks for each architecture.
  - Since each mission has different duration, distance from Earth, capabilities etc. the mitigation strategy and hence deliverables vary by mission.

Research Portfolio Overview

- **Main investment areas**
  - Space Radiation
  - Exploration Medical Capability
  - Human Health Countermeasures
  - Behavioral Health & Performance
  - Space Human Factors & Environmental Standards
  - ISS Research Capability
- **Multi-center program led by JSC**
  - Ames Research Center (space human factors, lunar dust toxicity, ISSMP, ExMC, advanced radiation monitoring)
  - Glenn Research Center (exercise, physiological modeling)
  - Langley Research Center (radiation modeling)
- **Collaboration with international partners and external organizations are important for maximizing return on investment**
  - Brookhaven, National Institutes of Health, National Space Biomedical Research Institute (NSBRI) Network, University of Texas Medical Branch (UTMB), Cleveland Clinic
  - European Space Agency (ESA), Russia, Japanese Aerospace Exploration Agency (JAXA), Canadian Space Agency (CSA)

Effects of Space Travel

- Radiation exposure
  - Galactic cosmic radiation
  - Solar proton events
  - Planetary surface radiation
- Bone density decrements
  - 1% per month in microgravity
  - Unknown effects in fractional *G*
  - Calcium excretion (renal stone risk)
- Muscle deconditioning
  - Dysuse atrophy
  - Difficulty upon return to Earth gravity

Effects of Space Travel

- Neurovestibular disturbances
  - Balance and perception problems
  - Space sickness
- Behavioral and performance
  - Small group dynamics
  - Estrangement
  - Depression
  - Cognition
  - Sleep disturbances

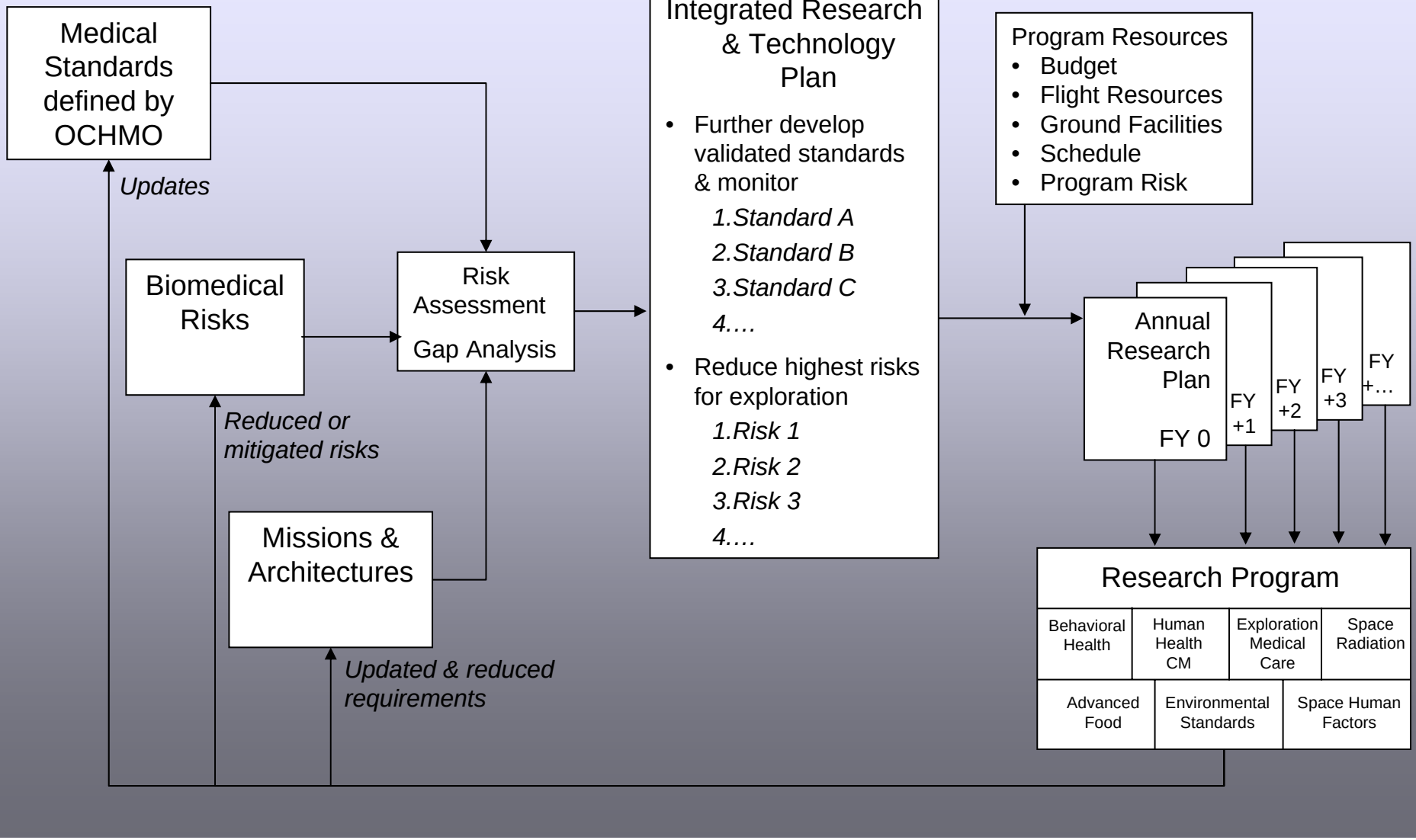
Effects of Space Travel

- Cardiovascular deconditioning
  - Cephalad fluid shift
  - Change in hemodynamics
  - Decrease in total red blood cell population
  - Potential decrease in cardiac muscle performance
- Nutrition
  - Decreased appetite
  - Changes in GI performance

Effects of Space Travel

- Potential effect on immune performance
  - Decreased response to:
    - Recall antigens
    - Polyclonal activators
  - No evidence of opportunistic infection to date
- Gastrointestinal changes
  - Increased transit time
- Orthostatic intolerance upon return to gravity

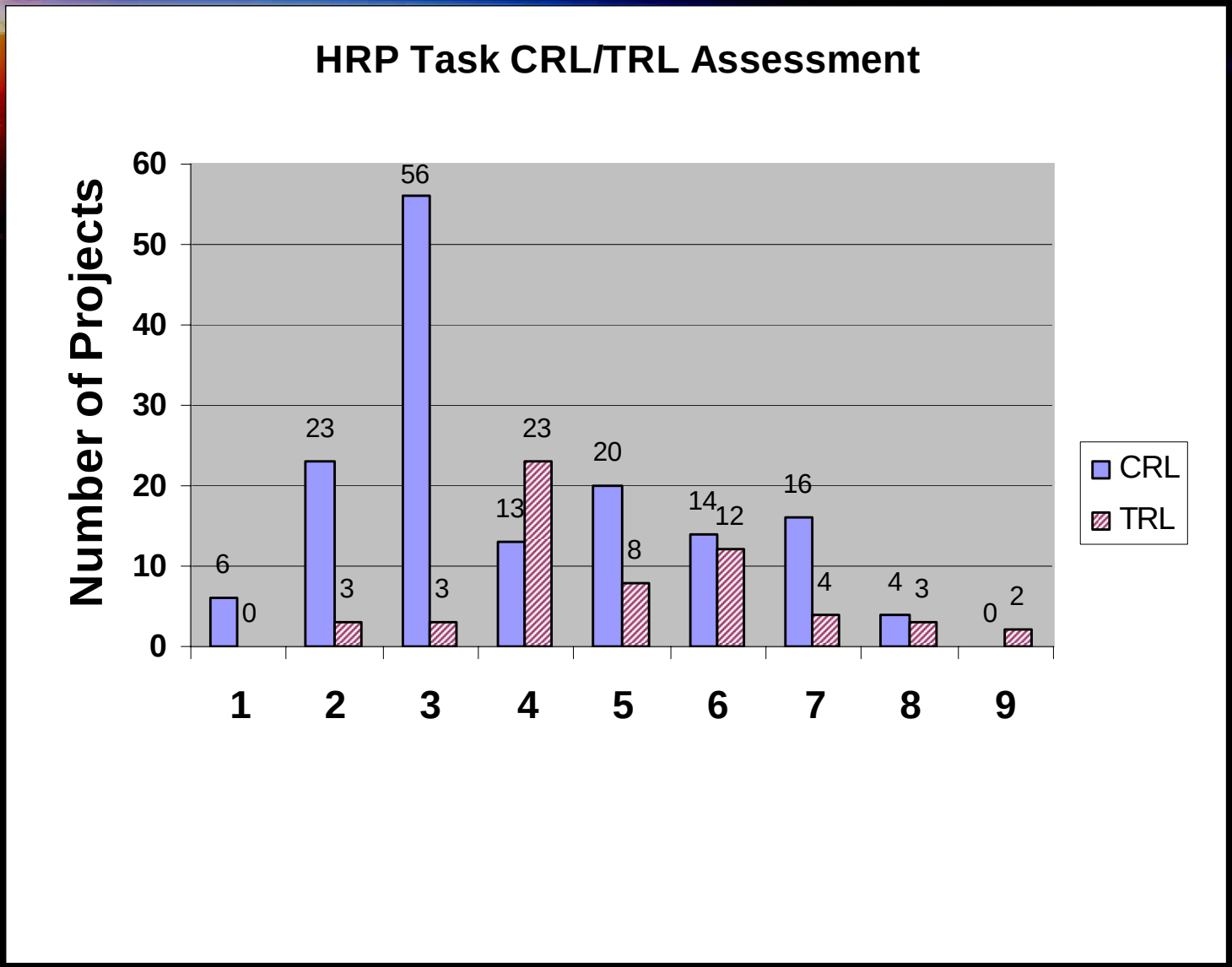
Human Research Program Investment Approach



CRL/TRL Definitions

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 counter-measures concept based on understanding of phenomenon.**	**Counter-measure Development**	
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.**		**Countermeasure 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**	

Current HRP Portfolio



Risk Management Analysis Tool

	Architectures					
	CEV (CEV to ISS)	**ISS** (6 Months)	**ISS** (1 Year)	**Moon** (<14 days)	**Moon** (Lunar Habitat)	**Mars**
Has the Risk Factor been verified? (Y/N)						
Probability of the Adverse Outcome						
Uncertainty Associated with the Outcome						
Impact of the Adverse Outcome						
Mitigation, Current and/or Proposed						
Cost/Benefit Trades (including risks of mitigation)						
Current Work						
Future Work						
Test Bed Required						

Research Venues

- Solicited- Grants
- Directed- Contracts, Intramural, Extramural
- Unsolicited- Offerings from academic institutions, industry, and private individuals
- Partnerships
  - Interagency
  - Space Act and Cooperative Agreements

Summary

- We will use a ‘standards to deliverables’ approach to risk mitigation
- Risk reductions will be assessed as research and technology developments progress through CRL/TRL 4-9
- The ISS, Moon, Mars will be used as platforms for research on human risks in space exploration