Human Research Program (HRP)
Countermeasure Development for Long Duration Crew Health

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OVERVIEW

- NASA Human Research Program
- NASA Spaceflight Human System Standard
- Human Health and Performance Risks for Spaceflight
- Countermeasure Development
- Countermeasure Validation
HUMAN RESEARCH PROGRAM FOUNDATION

- Evidence/Risk-based Management Approach
  - Program Architecture: Evidence $\rightarrow$ Risks $\rightarrow$ Gaps $\rightarrow$ Tasks $\rightarrow$ Deliverables
  - Framed by the risks to Human Health and Performance
  - Validity of risks is based on evidence from science, clinical, and operational research
  - Externally Reviewed by Institute of Medicine (IOM)

- Gaps in Knowledge, Technology, and Countermeasures Flow from Risks
  - Each Element has specific tasks budgeted within the program to address these gaps
  - Integrated Research Plan (IRP) baselined in December 2007 and updated annually contains the gaps and tasks required to address each risk
  - Externally Reviewed by Standing Review Panels

- Documented and communicated to external communities via
  Human Research Roadmap (http://humanresearchroadmap.nasa.gov)
NASA SPACEFLIGHT HUMAN SYSTEM STANDARD

• NASA STD-3001
• This standard is published by NASA to:
  • Provide a healthy and safe environment for crewmembers
  • Provide health and medical programs for crewmembers during all phases of space flight.
  • Optimize crew health and performance, and to
  • Prevent negative long-term health consequences due to space flight.

Standards are evidence based and modeled on those used by the United States Occupational Safety and Health Administration involving performance standards to set exposure-type limits and/or fitness for duty criteria.

- Fitness for Duty (FFD)
  - Minimum measurable capability or capacity for a given physiological or behavioral parameter that allows successful performance of all required duties. Functional capacity measured. (e.g. cardiovascular VO2 Max)

- Space Permissible Exposure Limits (PEL)
  - Quantifiable limit of exposure to a space flight factor over a given length of time (e.g. life time radiation exposure). Physical/chemical agent measured.

- Permissible Outcome Limits (POL)
  - POLs delineate an acceptable maximum decrement or change in a physiological or behavioral parameter, as the result of exposure to the space environment. Biological/clinical parameter measured. (e.g. limiting microgravity exposure to limit bone loss)
HUMAN HEALTH AND PERFORMANCE RISKS

NASA Health and Medical Technical Authority identified 32 Risks to meeting Standards that require research
Risks Reviewed by the National Academies’ Institute of Medicine

**Space Human Factors**
- Risk Associated with Poor Task Design
- Risk of Adverse Health Affects from Lunar Dust Exposure
- Risk Factor of Inadequate/Inefficient Food System
- Risk of Crew Adverse Health Due to Alterations in Host-microorganism Interactions
- Risk of Inadequate Human-Computer Interface
- Risk of Performance Errors Due to Training Deficiencies
- Risk of Inadequate Design of Human and Robot Integration
- Risk of an Incompatible Vehicle/Habitat Design

**Behavior, Health and Performance**
- Risk of Behavioral and Psychiatric Conditions
- Risk of Performance Errors Due to Sleep Loss, Circadian Desynchronization, Fatigue and Work Overload
- Risk of Performance Errors Due to Poor Team Cohesion and Performance, Inadequate Selection/Team Composition, Inadequate Training, and Poor Psychosocial Adaptation

**Space Radiation Risks**
- Risk of Radiation Carcinogenesis
- Risk of Acute Radiation Syndromes Due to Solar Particle Events
- Risk of Acute or Late Central Nervous System Effects from Radiation Exposure
- Risk of Degenerative Tissue or other Health Effects from Radiation Exposure

**Human Health Countermeasures**
- Risk of Accelerated Osteoporosis
- Risk of Orthostatic Intolerance During Re-Exposure to Gravity
- Risk Factor of Inadequate Nutrition
- Risk of Compromised EVA Performance and Crew Health Due to Inadequate EVA Suit Systems
- Risk of Impaired Performance Due to Reduced Muscle Mass, Strength and Endurance
- Risk of Bone Fracture
- Risk of Intervertebral Disc Damage
- Risk of Renal Stone Formation
- Risk of Cardiac Rhythm Problems
- Risk of Reduced Physical Performance Capabilities Due to Reduced Aerobic Capacity
- Risk of Crew Adverse Health Event Due to Altered Immune Response
- Risk of Impaired Ability to Maintain Control of Vehicles and Other Complex Systems
- Risk of Therapeutic Failure Due to Ineffectiveness of Medicine
- Risk of long-term visual changes due to microgravity exposure
- Risk of Decompression Sickness
- Risk of Injury from Dynamic Loads

**Medical Capability**
- Risk of Inability to Adequately Treat an ill or Injured Crew Member
## COUNTERMEASURE DEVELOPMENT

### Potential Areas requiring Countermeasures
- Cardiac disease
- Immune System

<table>
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<th>Areas Requiring Countermeasures</th>
<th>Countermeasures in Development</th>
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<td>Behavioral Health</td>
<td>Sleep Protocols and Medications, Lighting Protocols, Training Strategies and Protocols for Team Cohesion, Interactive Tools for Behavioral Health</td>
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<td>Bone, Muscle</td>
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<td>Aerobic Capacity</td>
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<td>Radiation Exposure</td>
<td>Nutrition, Pharmaceuticals, Shielding</td>
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COUNTERMEASURE DEVELOPMENT EXAMPLES

Advanced Exercise Concepts

Fluid Redistribution Countermeasures

Solid State Lights and Protocols for the ISS

Advanced Food Systems
COUNTERMEASURE MONITORING TECHNOLOGIES

Point-of-Care Lab Analysis for ISS

Non-Invasive Intracranial Pressure Measurements

Behavior and Neurological Function Assessment Tools

Remote Guidance Ultrasound Techniques
• After laboratory development, Countermeasures are further validated in operational or flight-like Analogs.
Early ISS resistive exercise was only capable of providing 300 lbs of resistance and was found to be insufficient for maintaining muscle and bone.

“These data document that resistance exercise, coupled with adequate energy intake . . . can maintain bone in most regions during 4- to 6-month missions in microgravity. This is the first evidence that improving nutrition and resistance exercise during spaceflight can attenuate the expected BMD deficits previously observed after prolonged missions.”
S. Smith et al, JBMR, September 2012

Current ISS resistive exercise is capable of providing 600 lbs of resistance and initial data look promising.
“Human space flight remains an endeavor with substantial risks, and these risks must be identified, managed, and mitigated appropriately to achieve the nation’s goals in space.”

(A Risk Reduction Strategy for Human Exploration of Space, National Academies, Institute of Medicine, 2006)