Human Health and Performance – A Risk Mitigation Approach for Missions to the Moon and Mars

NASA Advisory Council
Exploration Committee

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Human Health and Performance – A Risk Mitigation Approach for Missions to the Moon and Mars

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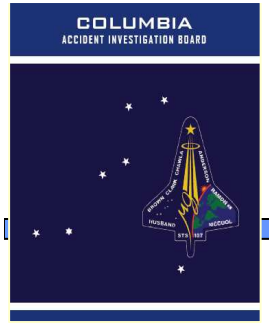
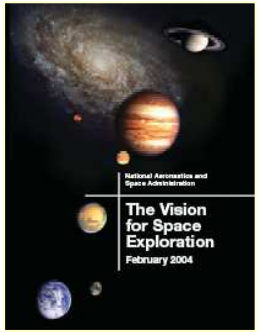
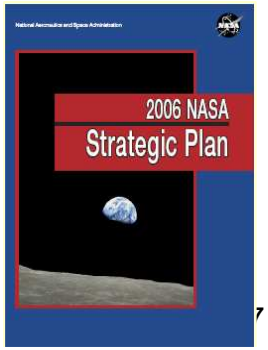
Presentation Overview

- Background
- Recommendations
  - IOM Safe Passage Report
  - CAIB Report
  - IOM Review of the Bioastronautics Roadmap
  - HQ Cross-Functional Working Group
- Health and Medical Technical Authority
- Human System Space Flight Standard: NASA-STD-3001
- Standards to Deliverables Process
- Risk Management Process
  - Evidence Base
  - Space Flight Human System Standards
  - Risk Mitigation Analysis Tool
- Summary and Status

Background







- 2001, Institute of Medicine Safe Passage published
- 2003, CAIB Report issued
- 2004, Vision for Space Exploration released
- 2005, Exploration Systems Architecture Study
- 2005, Institute of Medicine Report regarding the Bioastronautics Roadmap
- 2006 NASA Strategic Plan

Institute of Medicine Recommendations

- Review of Bioastronautics Roadmap
  - Incorporate an evidence-based risk assessment and communication process into the risk identification and reduction approach
  - Risks and mitigation strategies should be represented separately for assessment and comparison

Standards to Deliverables Process

- Standards
  - Standards implement health and medical policy
  - The first step in risk mitigation is establishing standards to define an acceptable level of risk
  - Standards are based on the best available information and evaluated against the space flight environment
  - Operational experience is assessed to inform the standards
  - Research projects are defined to fill the gaps in knowledge
- Deliverables
  - Desirable solutions to research and/or technology questions that reduce or manage the risks to human exploration

Space Flight Human System Standard NASA-STD-3001

- Includes human health and performance standards (permissible outcome or exposure limits) and levels of medical care (Volume 1) and habitability and environmental health standards (Volume 2)
- Guides biomedical research and medical/environmental systems development
- Development/revision is initiated by the CHMO and developed by JSC with participation of other centers and external experts as appropriate

Space Flight Human System Standard NASA-STD-3001

- Volume 1: Crew Health
  - Human health and performance standards
    - Fitness-for-Duty Aerobic Capacity
    - Fitness-for-Duty Sensorimotor
    - Fitness-for-Duty Behavioral Health and Cognition
    - Fitness-for-Duty Hematology and Immunology
    - Permissible Outcome Limit for Nutrition
    - Permissible Outcome Limit for Muscle Strength
    - Permissible Outcome Limit for Microgravity-Induced Bone Mineral Loss Performance
    - Space Permissible Exposure Limit for Space Flight Radiation Exposure

Space Flight Human System Standard NASA-STD-3001

- Volume 1: Crew Health, continued
  - Levels of Medical Care
  - Health and medical diagnosis, intervention, treatment, and care standards
  - Countermeasures
  - References crewmember selection and periodic certification standards
  - Training standards

Space Flight Human System Standard NASA-STD-3001

- Volume 2: Habitability and Environmental health
  - Air and water quality standards
    - Terrestrial data
    - Proposed and reviewed for a closed environment with prolonged exposures
  - Habitability
  - Human factors
  - Retained requirements
    - Design options retained in a reference handbook
  - Under Agency review

Risk Management: An Evidence Based Approach

- Need to regularly collect/evaluate the accumulated data and evidence
- Use evidence base to make recommendations to create/alter health and medical human system standards and/or requirements
- The Human Research Program discipline reviews have been implemented to understand our current database and develop research requirements
- Pursue collaborative alliances to broaden and strengthen evidence base
  - NIH-NASA Memorandum of Understanding for collaborative research
  - Proposed FAA-NASA Memorandum of Agreement to collect and analyze the biomedical data of commercial space flight participants and crews

Risk Mitigation Analysis Tool (RMAT)

- Collects the current status of work in developing and addressing compliance with standards for identified risks and/or risk factors
- Assess the need for mitigation to stay within the standard for a particular mission - directorate work should be tailored and phased accordingly
- Facilitates documentation and baselining of the risk management approach - allows us to assess gaps and provide traceability of our work
- The tool flows from a standard to a deliverable for a particular mission

Risk Mitigation Analysis Tool (RMAT)

Risk (Adverse Outcome):
Any future event with a negative consequence that has some probability of occurrence. There are two categories of risk based on this definition: those with defined probabilities are risks; those with undefined probabilities are potential risks. Crew health and performance risks and potential risks could fall into several categories: Clinical (Acute and/or Long Term), Unacceptable Performance Decrement, System, or Process Failure (Hardware, Software, Flight Rule, etc.).

Human Health and Performance Standard:
Statement of the acceptable level of risk based on the best available evidence.

Risk Factor (Underlying the adverse outcome):
Characteristic or variable that underlies the risk or potential risk and is a target for research and/or mitigation.

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 (without current or proposed mitigation)						
Uncertainty Associated with Outcome						
Impact of the Adverse Outcome						
Mitigation, Current and/or Proposed						
Probability of the Adverse Outcome (with current/proposed mitigation)						
Cost/Benefit Trades (Including risks of mitigation)						
Current Work						
Future Work						
Test Bed Required						

Example: Risk of Radiation Induced Carcinogenesis

Risk (Adverse Outcome): Radiation Carcinogenesis

Human Health and Performance Standard: Risk of Exposure Induced Death (REID) <3% at a 95% confidence level with application of ALARA below this risk limit

Risk Factor contributing to the outcome: Exposure to space radiation including galactic cosmic rays (GCR) and solar particle events (SPE), mission length and timing dependent

Radiation Carcinogenesis: 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)	Y	Y	Y	Y	Y	Y
Probability of the adverse outcome (without current or proposed mitigation)		*PRA calculations: Females 0.7%, Males 0.6%	*PRA calculations: Females 1.3%, Males 1.2%		*PRA calculations: Females 1.5%, Males 0.8%	*PRA calculations: Females 5.0%, Males 4.5%
Uncertainty associated with outcome		0.3-1.9% 0.2-1.5%	0.5- 4.0% 0.4- 3.0%		0.5- 5.0% 0.5- 4.0%	1.5-18% 1.5-15%
Impact of the Adverse Outcome		1) individual, acute health 2) mission impact	1) individual, acute health 2) mission impact	1) individual, acute health 2) mission impact 3) program impact	1) individual, acute health 2) mission impact 3) program impact	1) individual, acute health 2) mission impact 3) program impact
Mitigation, Current and/or Proposed	1) shielding 2) monitoring to reduce SPE threat	1) shielding 2) monitoring to reduce SPE threat	1) shielding 2) monitoring to reduce SPE threat	1) shielding 2) monitoring to reduce SPE threat 3) maximize surface time to use planetary shielding	1) shielding 2) monitoring to reduce SPE threat 3) maximize surface time to use planetary shielding	1) shielding 2) monitoring to reduce SPE threat 3) maximize surface time to use planetary shielding
Probability of the Adverse Outcome (with current/proposed mitigation)						
Cost/Benefit Trades (Including risks of mitigation)	1) vehicle design impacts 2) cost impacts 3) mission planning	1) cost impacts 2) mission planning impacts	1) cost impacts 2) mission planning impacts	1) vehicle design impacts 2) cost impacts 3) mission planning	1) vehicle design impacts 2) cost impacts 3) mission planning	1) vehicle design impacts 2) cost impacts 3) mission planning
Current Work		1) optimize modeling technique 2) refine confidence interval	1) optimize modeling technique 2) refine confidence interval		1) optimize modeling technique 2) refine confidence interval	1) optimize modeling technique 2) refine confidence interval
Future Work		Describe appropriate mitigation for lunar habitat mission	Describe mitigation for Mars mission; transit, & surface operations		Revision of the standard to conform with ALARA	Revision of the standard to conform with ALARA

Draft RMAT

Crew Health and Performance Risk Management Process Summary

- Review and reduce data and evidence regularly
- Establish standards to define an acceptable level of risk
- Use an Agency level approach with JSC leadership and participation from ARC, GRC, and LaRC
- Use an analysis and communication tool to document and baseline our risk management approach, assess gaps in our approaches and provide traceability of our work
- Focus deliverables to the highest priority human health risks, specific to the mission
- Review by the Health and Medical Technical Authority of appeals or waiver requests against standards and requirements

Exploration Committee Observations

- New way of “doing business” by Life Sciences at JSC
- Great potential for methodically establishing standards, developing deliverables, and establishing mission-related “guidelines”
- Enables Life Sciences to better communicate with other programmatic elements regarding risk trades
- Different astronaut population demographics might influence tailoring of acceptable levels of risk
- Caution: the space environment is one that is vastly different from the typical workplace environment. Should consider utilization of terminology that recognizes this difference and minimizes misleading analogies.

Exploration Committee

- No formal recommendation
- Ad hoc Biomedical Subcommittee will continue to monitor