DRAFT

From Research to Requirements: Getting Humans to Mars

Dr. Jennifer Rochlis Zumbado

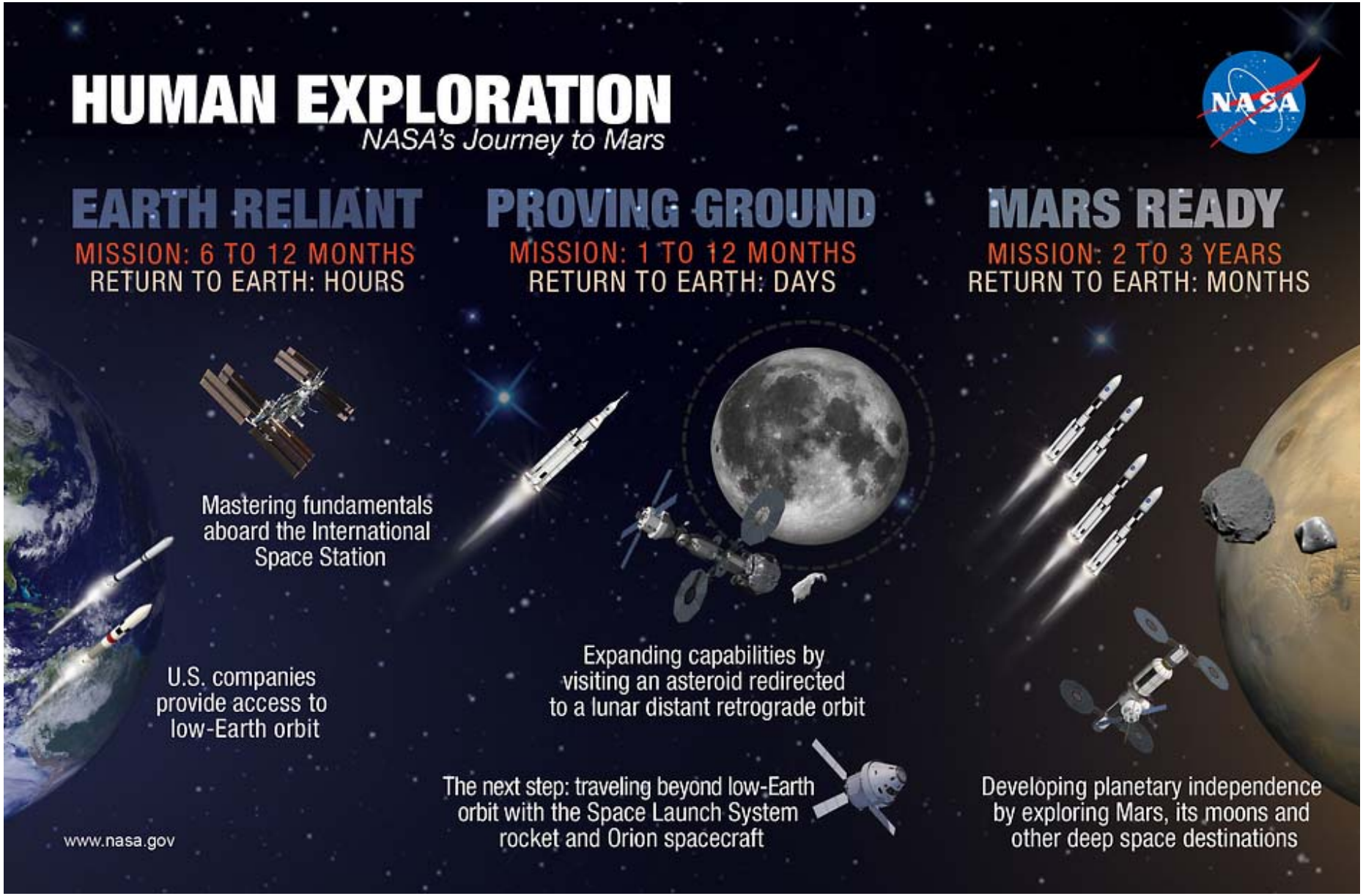
NASA Johnson Space Center

AHFE, July 2015

Human Space Exploration

- Where we're going
- What human challenges we're researching
- How we translate research into requirements and design

Destination - MARS



NASA's Human Research Program (HRP)

Mission: To enable space exploration beyond low Earth orbit by reducing the risks to human health & performance through a focused program of:

- Basic, applied, and operational research,

leading to the development and delivery of:

- Human health, performance, and habitability standards
- Countermeasures and risk mitigation solutions
- Advanced habitability and medical support technologies

HRP Overview

Established in 2005 to focus NASA's research on the highest risks to human health and performance during exploration missions.

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

National Research Program directly aligned with human exploration goals

- NASA Mission: *"Driving advances in science, technology exploration to enhance knowledge, education, economic vitality, and stewardship of Earth in the area of Human Health and Performance."*
- Example: Strategic Goal 1: *Extending and sustaining activities across the solar system*

Highest health and performance risks associated with exploration missions have been identified, documented, reviewed, and are actively managed

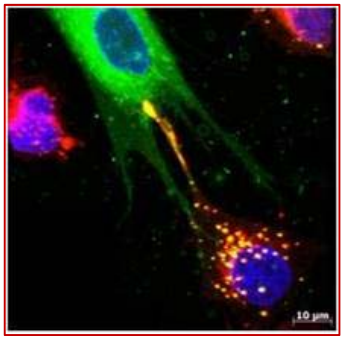
Research underpinnings have been established by the National Academies

Independent, external scientific review used extensively

Collaborative research with Internationals and other U.S. Agencies

Products include:

- Information to design exploration architectures, vehicles, and missions
- Countermeasures
- Research deliverables that define space medical, environmental and human factors standards (Standards define acceptable human health risk)
- Technologies and Tools



Cell fusion after exposure to Simulated Space Radiation

Clay Anderson centrifuges Nutrition blood samples during Increment 15

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

Human System Risks Inform Research Focus Areas

Primary Hazards Leading to HRP Risks

- **decreased gravity**
  (including gravity transitions & launch & landing loads)
  bone, muscle, cardiovascular, sensorimotor, nutrition, behavior, performance, immunology, human factors, clinical medicine
- **isolation/confinement & altered light-dark cycles**
  Behavior, performance
- **hostile/closed environment**
  (including habitability: atmosphere, microbes, dust, volume/configuration, displays/controls,…)
  Behavior, performance, nutrition, immunology, toxicology, microbiology
- **increased radiation**
  immunology, carcinogenesis, behavior, performance, tissue degeneration, pharmaceutical stability…
- **distance from Earth**
  Behavior, performance, autonomy, food systems, clinical medicine

Note that severity generally increases with mission duration.

Human System Risks Tracked by NASA's Health & Medical Technical Authority

Altered Gravity Fields

1. Risk of spaceflight-induced intracranial hypertension/vision alteration
2. Risk of urinary retention
3. Risk of space adaptation back pain
4. Risk of intervertebral disc damage upon and immediately after re-exposure to gravity
5. Risk of renal stone formation
6. Risk of bone fracture due to spaceflight induced bone changes
7. Risk of impaired performance due to reduced muscle mass, strength & endurance
8. Risk of reduced physical performance capabilities due to reduced aerobic capacity
9. Risk of impaired control of spacecraft, associated systems and immediate vehicle egress due to vestibular / sensorimotor alterations associated with space flight
10. Risk of cardiac rhythm problems
11. Risk of orthostatic intolerance during re-exposure to gravity
12. Risk of crew adverse health event due to altered immune response
13. Risk of adverse health effects due to alterations in host-microorganism interaction
14. Risk of injury from dynamic loads
15. Risk of vascular disease associated with spaceflight

Radiation

1. Risk of space radiation exposure on human health

Distance from Earth

1. Risk of unacceptable health and mission outcomes due to limitations of in-flight medical capabilities
2. Risk of ineffective or toxic medications due to long term storage
3. Risk of performance errors due to training deficiencies

Isolation/Confinement

1. Risk of performance decrements due to adverse behavioral conditions

Concerns/Watch list

1. Concern of clinically relevant unpredicted effects of medication

Hostile/Closed Environment

1. Risk of toxic exposure
2. Risk of acute and chronic carbon dioxide exposure
3. Risk of hearing loss related to spaceflight
4. Risk of reduced crew performance due to hypobaric hypoxia
5. Risk of injury and compromised performance due to EVA operations
6. Risk of decompression sickness
7. Risk of injury from sunlight exposure
8. Risk of incompatible vehicle/habitat design
9. Risk of inadequate human system interface design
10. Risk of performance decrement or crew illness due to an inadequate food system
11. Risk of adverse health effects of celestial dust exposure
12. Risk of performance errors due to fatigue resulting from sleep loss, circadian desynchronization, extended wakefulness, or work overload
13. Risk of plasma charging

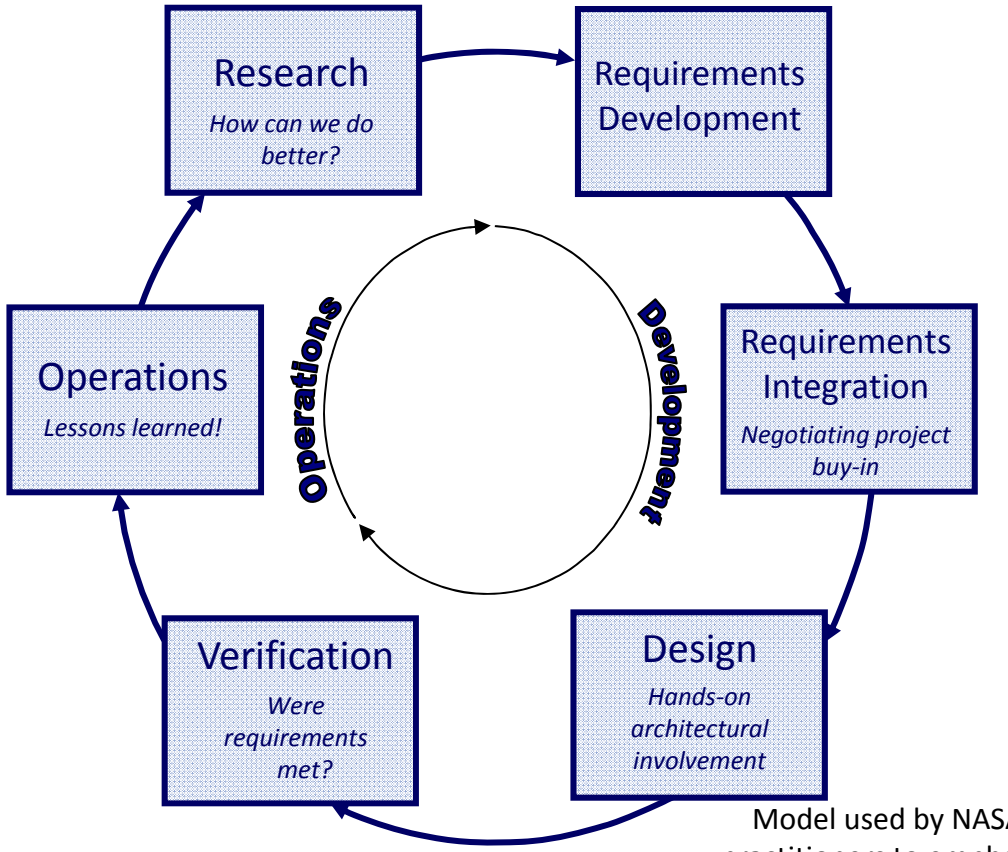
Human Factors: From Research to Design

"If human factors engineering is done properly at the conceptual and design phase, the cost is high, but paid only once. If training must compensate for poor design, the price is paid every day."

---Earl L. Wiener, "Cockpit Automation"

"We spend a lot of time designing the bridge, but not enough time thinking about the people who are crossing it."

---Dr. Prabhjot Singh

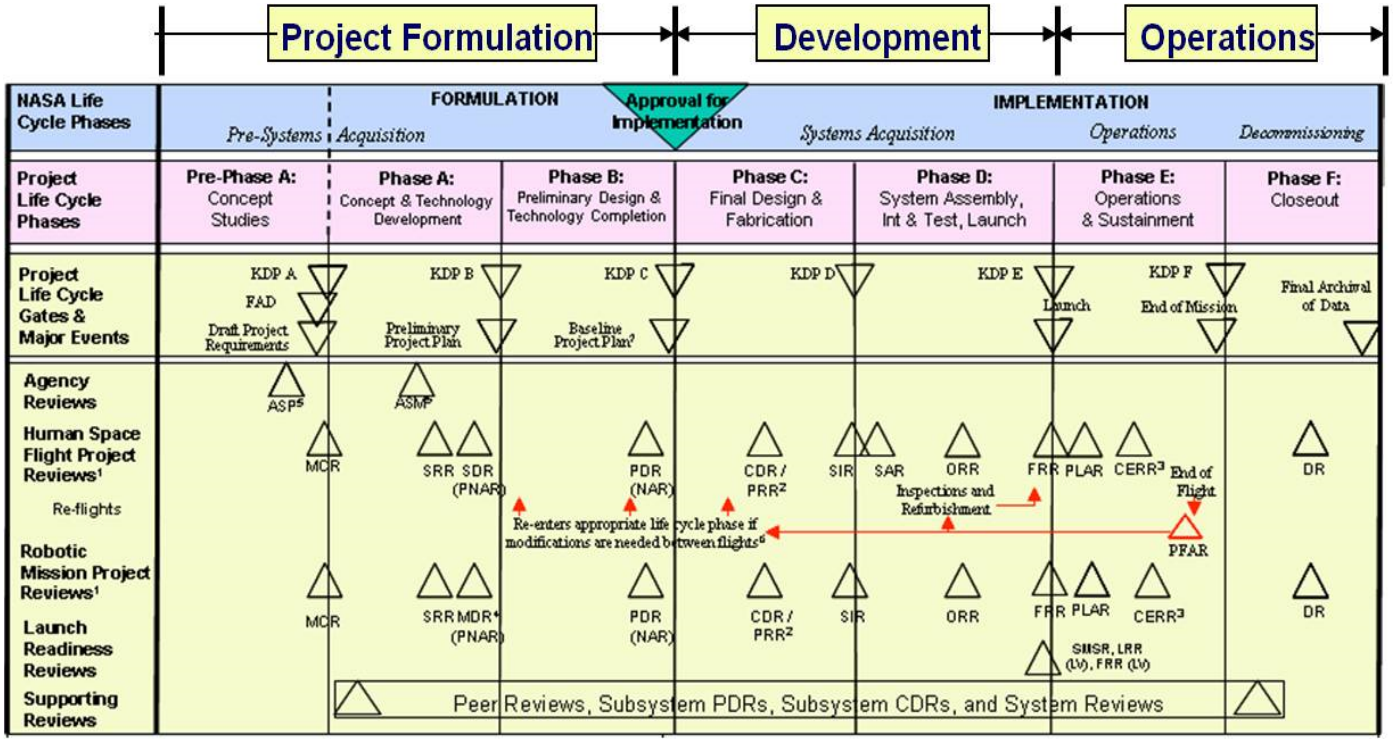


Model used by NASA HF practitioners to emphasize needed competencies

The Systems Engineering Life-Cycle

As with most major government acquisitions, human spaceflight programs follow a Systems Engineering Life-Cycle

- Major phases: Formulation → Development → Operations



To be cost effective, integration of human concerns must occur as early as possible in the life-cycle!

Human Systems Integration

Human Systems Integration is a process that ensures human capabilities and limitations are effectively considered in mission and system design and development

- HSI Approach
  - Utilizes well-known Systems Engineering (SE) processes (structured)
  - Treats the human at the same level as hardware and software
  - Can be applied to any size of project or program
  - Can be applied without regard to certification methodology
  - Applies to both flight and ground personnel
  - Enables a collaborative environment early in the development cycle
- HSI Benefits
  - Aims to reduce total ownership cost & maximize total system performance
  - Small investment during development = big return during operations
    - 80% of costs are “locked in” with early design decisions
  - Drives efficiencies to reduce crew time
    - Simplified operations, maintenance, and logistics

NASA HSI Domains

Requirements Development and Integration

Readiness of Standards has been critical to success

<u>Standards: NASA-STD-3001</u>

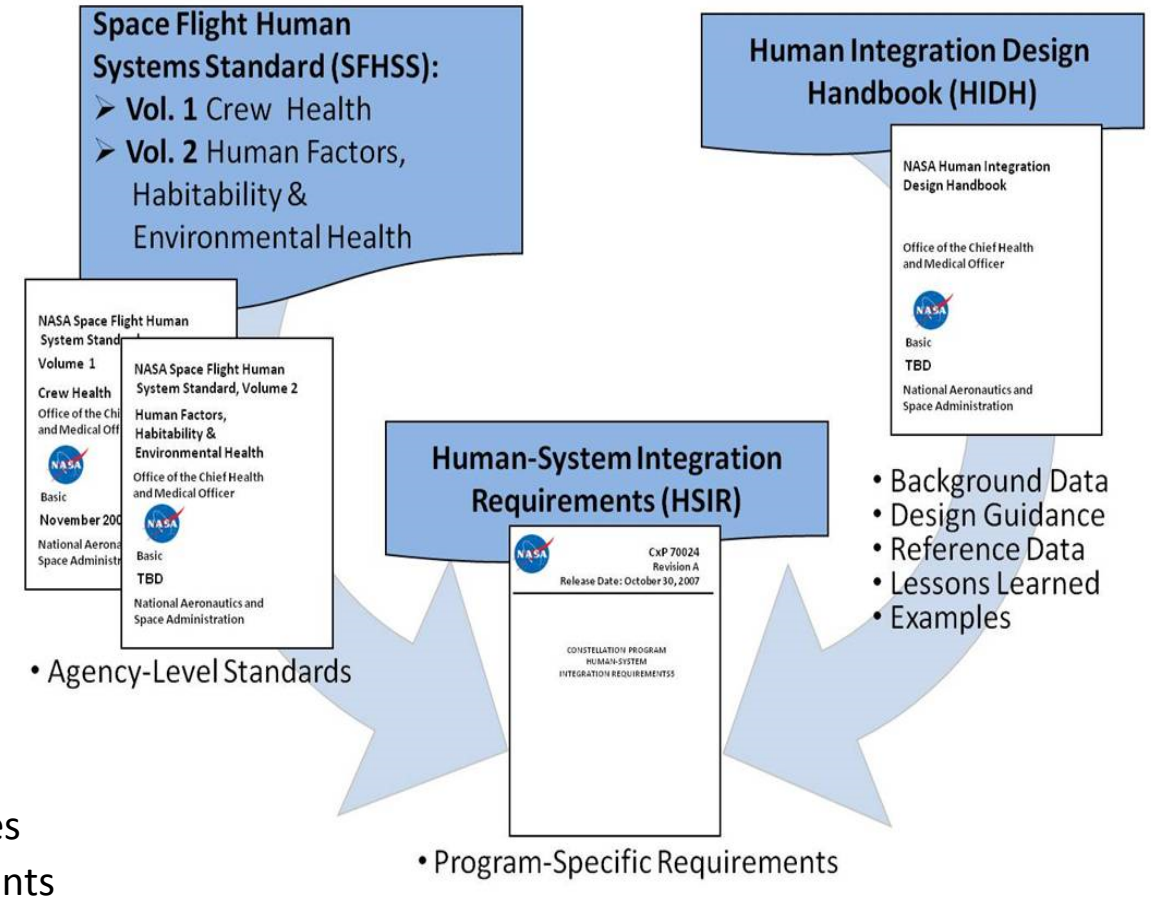
Space Flight Human Systems Standards

<u>Program-Unique Requirements</u>

Derived from NASA-STD-3001 for the International Space Station and Constellation Programs

Topics:

- Architecture
- Maintainability
- Facility Management
- Health Management
- Extravehicular Activity (EVA)
- Human Performance Capabilities
- Natural and Induced Environments
- Anthropometry, Biomechanics and Strength
- User Interfaces
- Hardware and Equipment



Summary

Human Systems Integration must reach the same level of maturity, rigor and respect as Systems Engineering & Integration in the Development Cycle of human spaceflight programs & projects

- Also referred to as a “Human-Centered Design” strategy

We send humans into space for a reason...

- How can we best enable and equip them to accomplish their mission objectives?

Remember...

- All engineering for over 10,000 years has existed to meet human needs, objectives, and capabilities
- All engineering is Human Engineering...