

Human Systems Integration at NASA: From Research to Implementation

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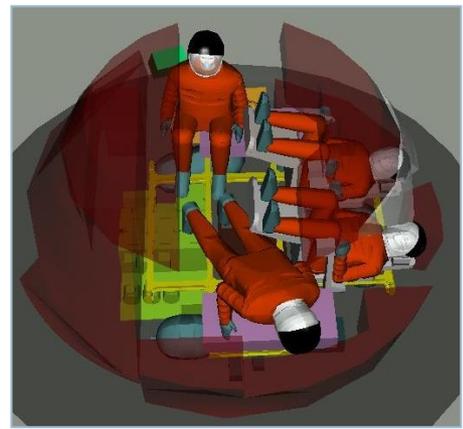
Human Research Program

NASA Johnson Space Center



Human Systems Integration at NASA

- HSI-related Research
 - Human Research Program
- HSI Implementation
 - HSI Heritage and where HSI stands today
- Forward Work





Destination Mars

HUMAN EXPLORATION

NASA's Journey to Mars



EARTH RELIANT

MISSION: 6 TO 12 MONTHS
RETURN TO EARTH: HOURS



Mastering fundamentals aboard the International Space Station

U.S. companies provide access to low-Earth orbit

PROVING GROUND

MISSION: 1 TO 12 MONTHS
RETURN TO EARTH: DAYS

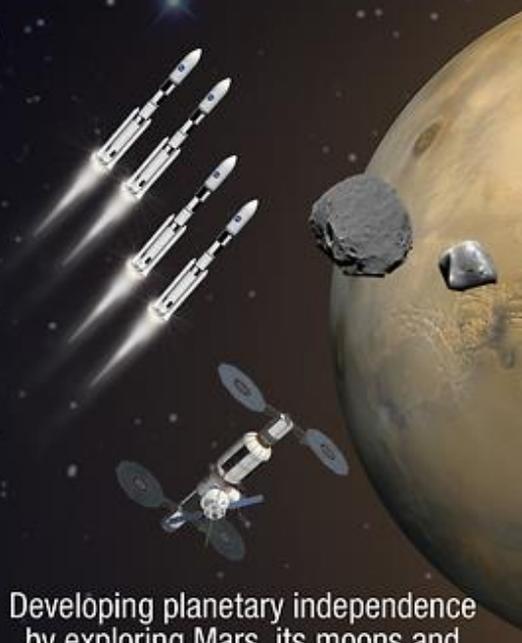


Expanding capabilities by visiting an asteroid redirected to a lunar distant retrograde orbit

The next step: traveling beyond low-Earth orbit with the Space Launch System rocket and Orion spacecraft

MARS READY

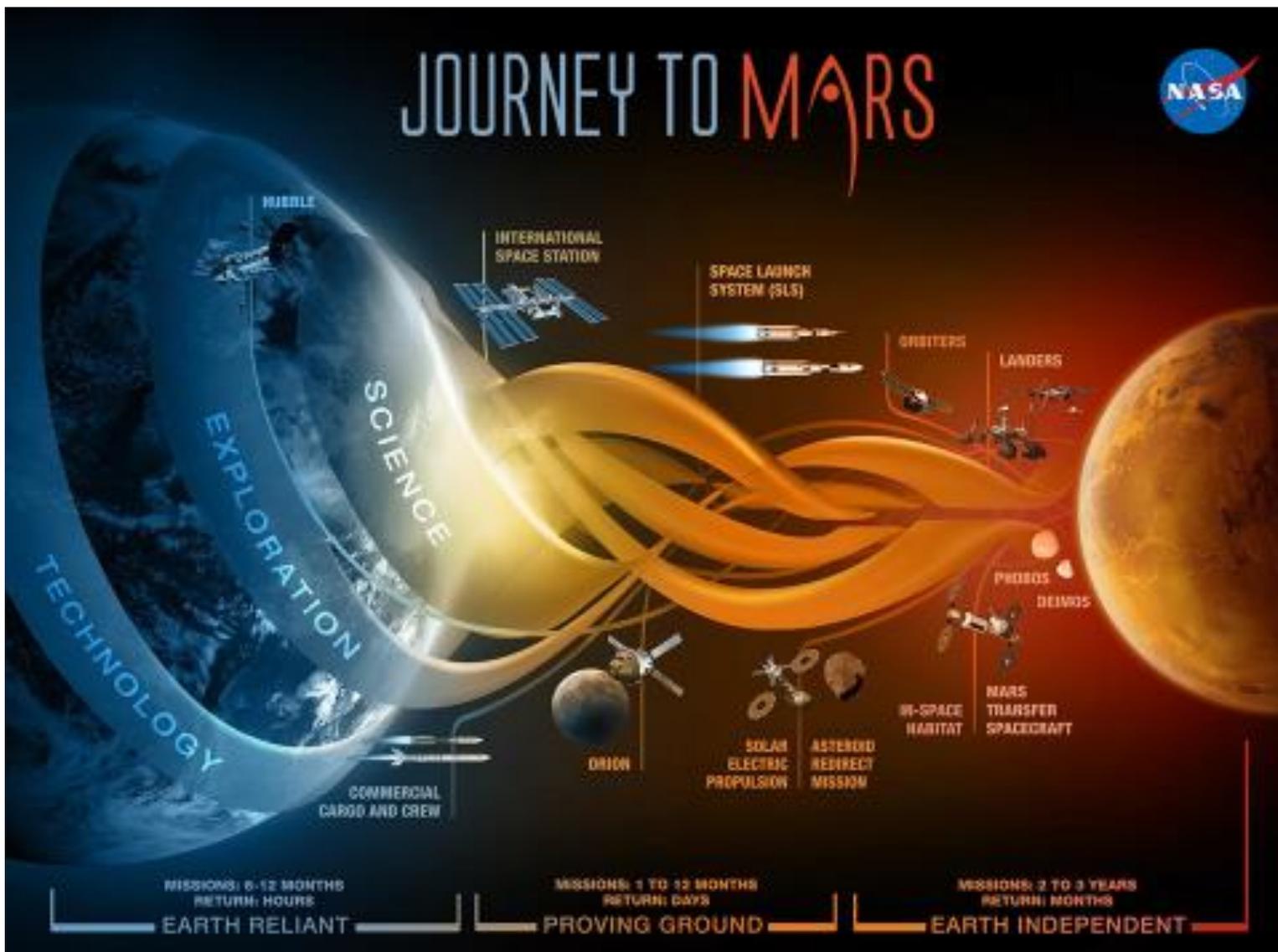
MISSION: 2 TO 3 YEARS
RETURN TO EARTH: MONTHS

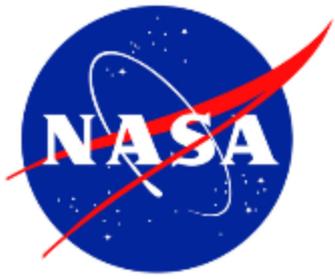


Developing planetary independence by exploring Mars, its moons and other deep space destinations



Destination Mars





HSI-related Research – Human Research Program



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



Primary Hazards to HRP Risks

- ▶ Decreased gravity
- ▶ Isolation and confinement
- ▶ Hostile/ closed environment
- ▶ Increased radiation
- ▶ Distance from Earth

[\(http://humanresearchroadmap.nasa.gov/explore/\)](http://humanresearchroadmap.nasa.gov/explore/)

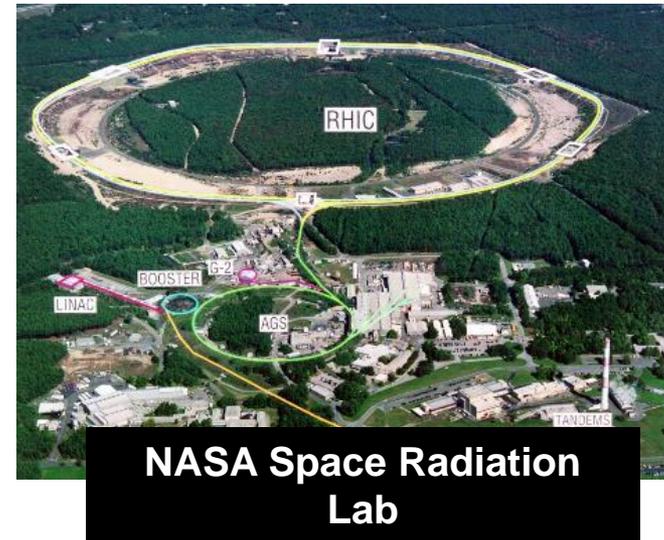


Components of HRP

- HRP is composed of six Elements
 - ▶ Human Health Countermeasures
 - ▶ *Physiology*
 - ▶ Behavioral Health and Performance
 - ▶ *Individual and interpersonal*
 - ▶ Space Human Factors and Habitability
 - ▶ *Interfaces between humans and vehicles/habitats*
 - ▶ Exploration Medical Capability
 - ▶ *Medical care for missions*
 - ▶ Space Radiation
 - ▶ *Radiation exposure and biological effects*
 - ▶ ISS Medical Project
 - ▶ *Infrastructure for flight experiments*
 - HRP funds the National Space Biomedical Research Institute (NSBRI) through a cooperative agreement to pursue research that complements the HRP portfolio
-



Venues for Conducting Research





Risk Mitigation

1. Determine Relevant Risks

- 33 risks and risk factors relevant to exploration within HRP research portfolio
- Focused on risks that could have a substantial negative effect on an exploration mission

2. Identify gaps in

- knowledge
- mitigation capability

3. Identify the research products required to fill the gaps

4. Generate research products

5. Validate research products (as needed)

6. Reassess gaps in a) knowledge or b) mitigation capability and return to step 3 as needed

Evidence → Risks → Gaps → Tasks → Deliverables



HRP Integrated Path to Risk Reduction

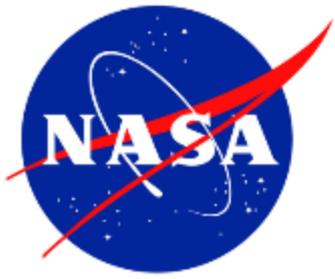
Planetary DRM (Mars)		FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28
Risks	LxC	ISS 1YM	Asteroid Phase A	CCP				EM-2	AARM	EM-3	EM-4	EM-5	ISS End	EM-6 (ARCM)		Mars Phase A
Space Radiation Exposure (Radiation)	3x4	Acute CNS Risk Characterized; NASA Cancer Risk Model v2020; Late CNS Risk Characterized; Acute CNS Stds Updated; Mars Phase A; NASA Cancer Risk Model 2025														
Cognitive or Behavioral Conditions (BMed)	3x4	Risk Factors Understood; Monitoring Tools Developed; CMs & Treatment Developed														
Medications Long Term Storage (Stability)	3x4	Most Common Usage Determined; Ground Stability Testing Complete; Stability Testing; TRV Validated; Stability Device; Med Usage Understood														
Vision Impairment/Intracranial Pressure (VIIP)	3x4	Potential CMs Identified; Risk Understood; CMs Validated; CMs Optimized														
Inadequate Food and Nutrition (Food)	3x4	Updated Nutritional Requirements to AFT; CM Validated; FOOD-02 Risk Understood; FOOD-01 Risk Understood; Mqts & Tools Validated; Nutrition CM Optimized														
Team Performance Decrements (Team)	3x4	Risk Understood; Standards Dev Measures Dev & Val; CMs Developed & Validated														
Inflight Medical Conditions (Medical)	3x4	Initial Concept of Operations; Integrated Medical System; ConOps for all DRMs; Pharmacy Recommendation; Select Technologies; Optimized Medical Syst														
Human-System Interaction Design (HSID)	3x4	HARI Risk Understood; TRAIN Risk Understood; NHV Validate; TASK CM Validated; HCI CM Validated; TRAIN CM Validated; HARI CM Validated														
Bone Fracture (Fracture)	2x4	Update Bone Stds; Fracture Risk Characterized; Osteo Risk Understood; Risk Quantification Updated; In-flight CM Validated														
Renal Stone Formation (Renal)	3x4	CMs Validated; Treatment Validated; Treatment Validated														
Sensorimotor Alterations (SM)	3x3	Standard Update; Risk Understood; CMs Developed Standard Validated; Inflight CMs Validated														
Injury from Dynamic Loads (OP)	3x3	Standards Update; Validated Analytical Tool; Risk Characterized, Standard Updated														
Altered Immune Response (Immune)	3x3	Determine clinical significance of altered imm response; Analog Identified; Risk Characterized/Identify CM; Inflight CM Validated														
Host-Microorganism Interactions (Microhost)	3x3	MICRO-02 Inform Risk; Inform Risk MICRO-04 & 05; MICRO-01 Inform Risk; Develop Virulence Countermeasures														
Injury Due to EVA Operations (EVA)	3x3	Suit Injury Data Identified; Update Suit Requirements; Updated Requirements for Suit, Crew, and Ops														
Hypobaric Hypoxia (ExAtm)	3x3	Short Duration Interim Review; Short term Chamber Eval Down-select; Risk Characterized														
Sleep Loss (Sleep)	3x3	Key Monitoring Tools Developed & Validated; Risk Understood; Key CMs Individualized & Validated; Integrated Monitoring Tools/CMs Validated														
Reduced Muscle Mass, Strength (Muscle)	3x3	Standard Update; Standard Validated; Inflight CM Validated Current Hardware; Inflight CM Validated Exploration Hardware														
Reduced Aerobic Capacity (Aerobic)	3x3	Standard Update; Standard Validated; Inflight CM Validated Current Hardware; Inflight CM Validated Exploration Hardware														
Celestial Dust Exposure (Dust)	TBD	Initial Risk Characterization Mars Dust														
Decompression Sickness (DCS)	3x3	Standard Update; Risk Understood; Risk Model Defined														
Orthostatic Intolerance (OI)	3x2	In-/Post-flight CM Validated														
Cardiac Rhythm Problems (Arrythmia)	3x4	Risk Understood														
Concern of Intervertebral Disc Damage (IVD)	TBD	Inflight Monitoring Method Validated; Risk Understood, CM Identified														
Concern of Effects of Medication (PK/PD)	TBD	Most Common Usage Determined; PK/PD Risk Characterization														

ISS Required
 ▲ Milestones Requires ISS
 ▼ ISS Mission Milestone
 Anticipated Milestone Shift
 ■ End ISS
 ISS Not Required
▲ Ground-based Milestones
▼ Mission Milestone

Hi LxC
 Mid LxC
 Low LxC
 Optimized
 Insufficient Data

} Accepted Risks

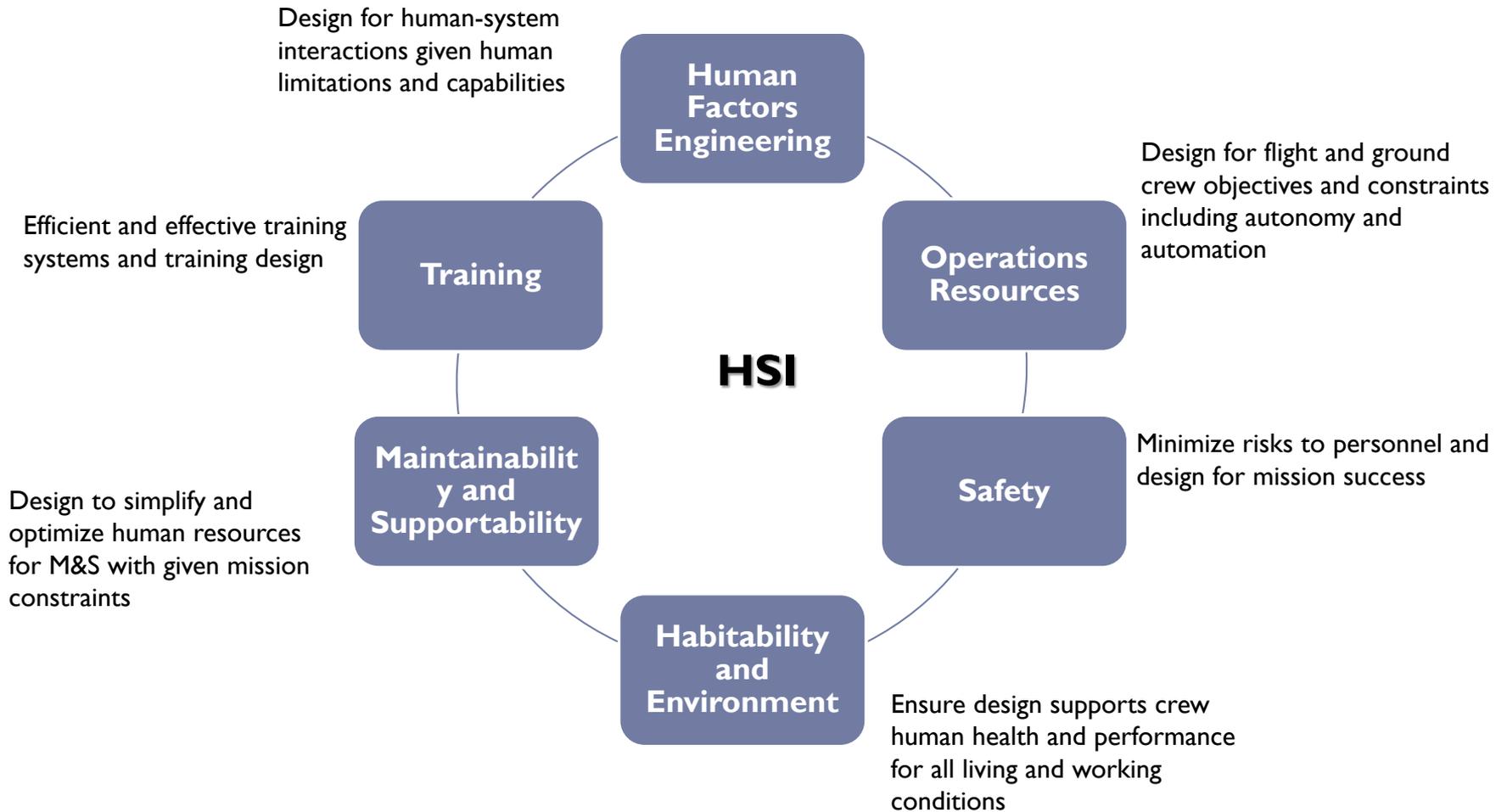
} Concerns



HSI Implementation – HSI Heritage and Where HSI stands today



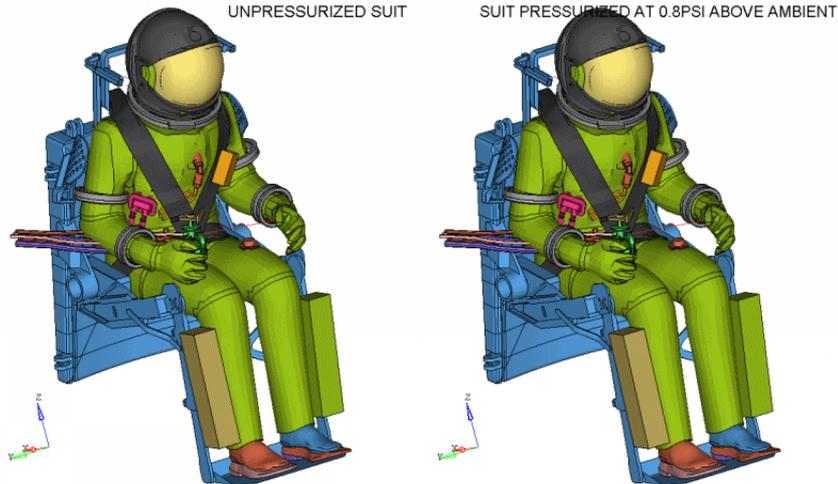
NASA HSI Domains





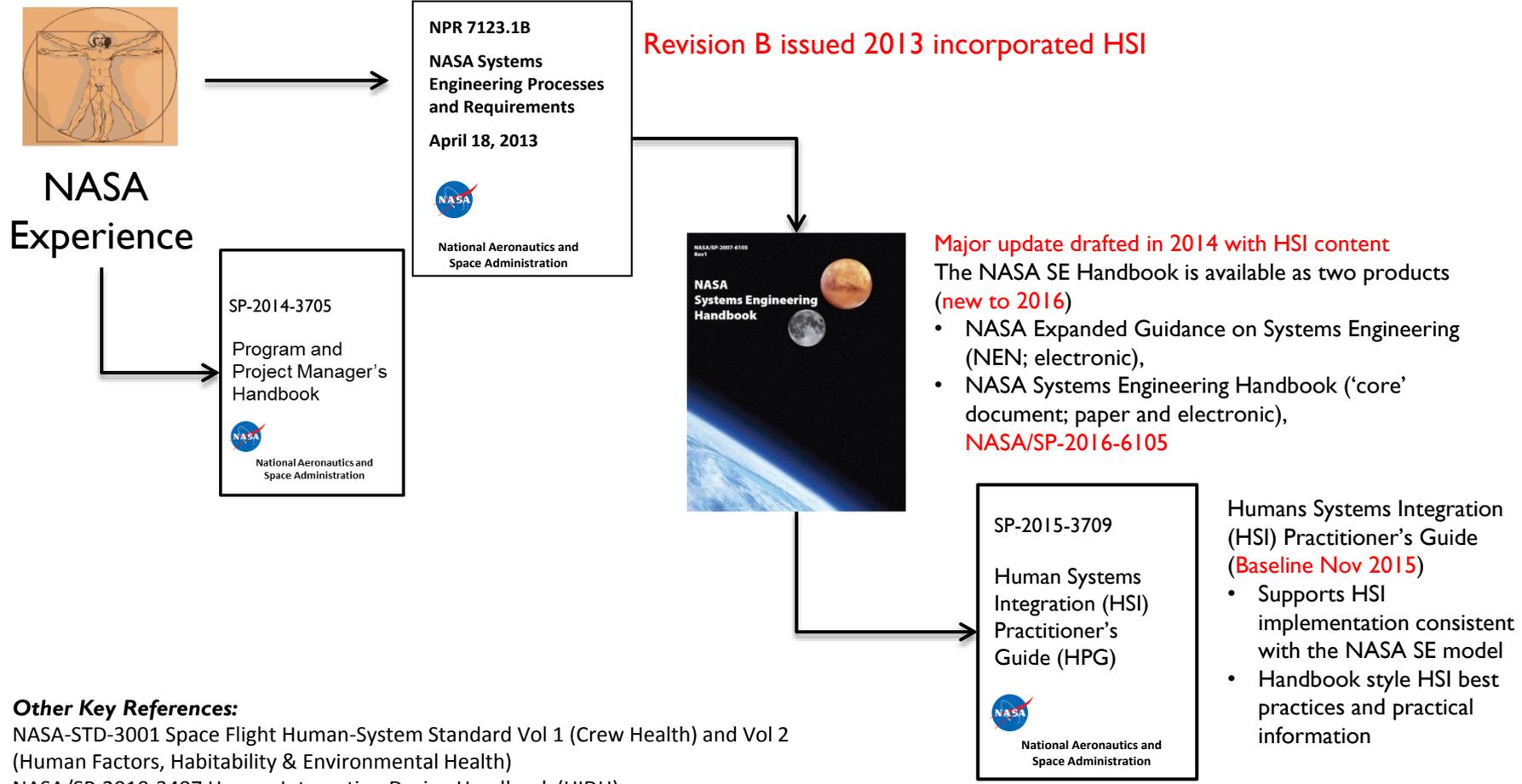
Where HSI Stands Today

- The JSC HSI Employee Resource Group has been active for over 4 years
- HSI practice has been inserted into the Agency NPR 8705.2B, the new revision of the Systems Engineering Handbook, and also the Program Management Handbook (7123.1B)
- The HSI Practitioner's Guide has been completed and released (NASA/SP-2015-3709)
- We have been actively engaged in numerous HSI Communities:
 - Multi-Center NASA HSI Steering Committee
 - Agency-wide Human Factors Engineering (HFE) Capability Leadership Team
 - National Defense Industry Association committee on HSI Metrics & Advocacy
 - Naval Post Graduate School HSI Curriculum Review
 - Department of Defense Joint HSI Working Group and Community of Interest





HSI “Document Tree”



Other Key References:

NASA-STD-3001 Space Flight Human-System Standard Vol 1 (Crew Health) and Vol 2 (Human Factors, Habitability & Environmental Health)

NASA/SP-2010-3407 Human Integration Design Handbook (HIDH)



The HSI Practitioner's Guide

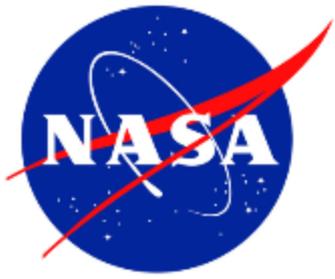
- Purpose: Provide guidance as to how to incorporate HSI into the existing NASA Systems Engineering (SE) processes and methodology
- Content of HSI Practitioner's Guide (SP-2015-3709)
 - Best practices and guidance for conducting HSI
 - Written for practitioner but has guidance for managers and disciplines
 - Phase-by-Phase guidance for activities and products, per NASA SE models, goes further and deeper than the SEHB
 - Skills-based tutorials and guidance for scaling for any size program/project
 - Checklists and annotated HSI Plan outline
- What background is the user expected to have?
 - It is expected is that the HSI lead/practitioner has come from a system engineering or human systems background and already has a good knowledge and experience with the SE HB.



Scaling HSI

- Recent agency emphasis has been on small-scope and/or advanced technology development projects
 - This offers an opportunity for early inclusion in pre-phase A activities (i.e., early conceptual design)
- Systems engineering (SE) and HSI activities may be tailored to a level appropriate for the degree/size/scope/development phase of the project
- The HSI Practitioner’s Guide provides guidance for scaling HSI (summarized below)

HSI Product	Large-Scale HSI Effort	Medium-Scale HSI Effort	Small-Scale HSI Effort
ConOps	Standalone Doc(s)	Possible Standalone Doc	Part of Project Docs
HSI Plan	Standalone Doc	Part of SEMP	Part of Project Docs
HSI Team	Required (Human Rated)	Recommended	As needed
Human in the loop	Significant Effort	Strong Effort	Modest Effort
Human-centered Design	Significant Effort	Strong Effort	Modest Effort

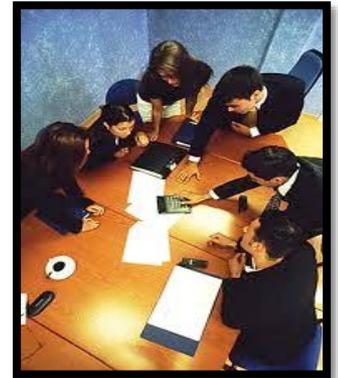


Forward Work



What is next?

- Next steps for HSI Implementation – From review of lessons learned in the DoD, NASA, and other environments, the following are key components we plan to implement HSI within systems engineering lifecycle processes
 - HSI Plan
 - HSI Team
 - Use of Metrics to track progress
- HSI Training Program for Program and Project managers, as well as HSI integrators and practitioners
- Governance Model
- HSI in Agile Development Process

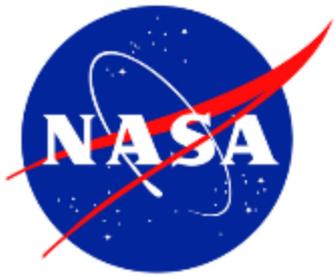




Thank You!



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Supplementary Charts



Component 1: HSI Plan

- The HSI plan is a “living” document that highlights the methods by which the program or project will ensure HSI is a core part of the lifecycle
 - **Goals** and **deliverables** for each phase of the lifecycle are defined
 - **Entry** and **exit criteria** with defined metrics are listed for each phase, review, and milestone
 - Roles and responsibilities are defined
 - Methods, tools, requirements, processes and standards are identified
 - Includes HSI issues, risks, and mitigation plans
- The HSI Plan can be a part of the Program/Project SEMP, a standalone document, or part of other project documentation depending on the HSI effort required
 - The plan is typically **updated** after successful completion of each phase to ensure relevance is maintained and as new issues arise
 - An HSI Plan template is published in the HSI Practitioner’s Guide (NASA/SP-2015-3709), Appendix A



Component 2: HSI Team

- An HSI Team is typically composed stakeholders and domain experts relevant to the program or project, as well as lead HSI practitioners
 - An HSI Team should be created before the program or project is initiated to help formulate the HSI Plan, but is required to be stood up by SRR per NPR 8705.2B
 - An HSI Team is almost always needed once the program or project starts in order to ensure the HSI Plan is implemented, facilitate resolution of HSI related issues during the lifecycle, identify human related cost drivers which increase life cycle costs or decrease system performance, and guide solutions
 - HSI Team Responsibilities:
 - Identify, resolve, and track HSI related issues as the program progresses
 - Generate/Review relevant system documents for major design reviews
 - Track entry and exit criteria for each lifecycle phase, review, and milestone
 - Ensure the most effective, efficient, and affordable design possible through tradeoff studies within and between domains, disciplines, and/or systems
 - Update the HSI Plan as the program or project proceeds through the SE lifecycle
 - Ensure Test and Evaluation (T&E) efforts are sufficient to verify/validate HSI requirements
-



Component 3: Metrics

- Without HSI metrics it is difficult to assess HSI success and progress
- Metrics should include well defined entry and exit criteria for each phase, review, and milestone of the lifecycle.
- Example metrics may include:
 - Using checklists to track consideration of key HSI related requirements
 - Crew time or efficiency measures for task completion
 - Training time estimates
 - Ensuring consideration of HSI has been included in relevant portions of formal plans, tests, and evaluations
 - Integration of constraints and requirements for logistics support, program resources and training plans
 - Conduction of inter-HSI domain trade-offs and identification of interactions with other major systems and subsystems
 - Formulation of plans to perform HSI review/assessments on hardware/software revisions that add/delete/defer capability not addressed in the capability documents