Human Systems Integration: Process to Help Minimize Human Errors, a Systems Engineering Perspective for Human Space Exploration Missions

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Human Systems Integration
EMPLOYEE RESOURCE GROUP

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Human-Systems Integration (HSI) Working Group

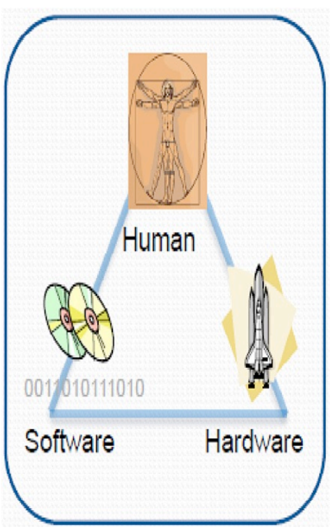
Outline

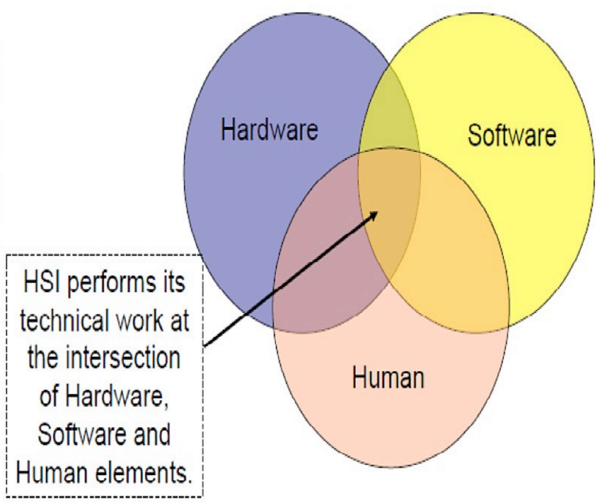
- Overview of HSI
- Terminology: System of Systems
  - Systems, Systems Engineering, Paradigm Shift
- History of HSI
  - Human factors, human factors engineering, human-centered design, human-machine interaction, human-computer interaction
- Human Error
  - Human action, failure, classification
  - Human reliability analysis methods
- Current practices of HSI in the DoD and NASA
- HSI activity at NASA (Practitioner's Guide)
  - Human in the loop evaluation, usability, workload, simulations, decision making

Human Systems Integration

"Interdisciplinary technical and management processes for integrating human considerations within and across all system elements; an essential enabler to systems engineering practice. The HSI processes facilitate tradeoffs among the human-centric domains without replacing individual domain activities, responsibilities, or reporting channels."

-INCOSE-





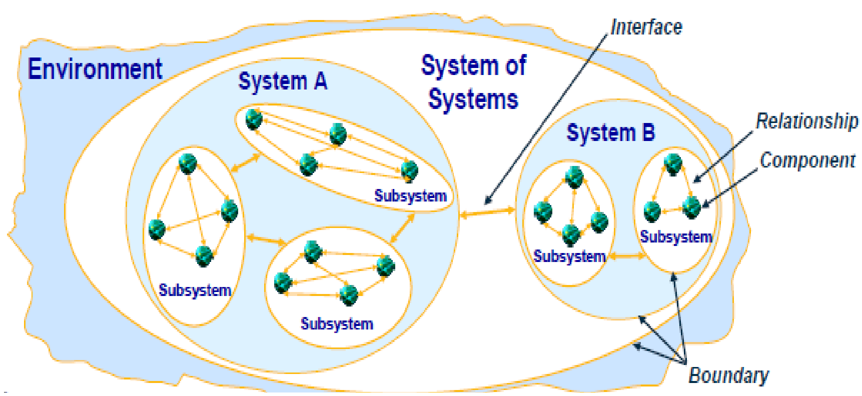
Enables better error management in human space missions

System of Systems

System:

A functionally, physically, and/or behaviorally related group of regularly interacting or interdependent elements; that group of elements forming a unified whole

-SEBoK



Systems Engineering:

Interdisciplinary approach and means to enable the realization of successful systems

-INCOSE

Systems of Systems:

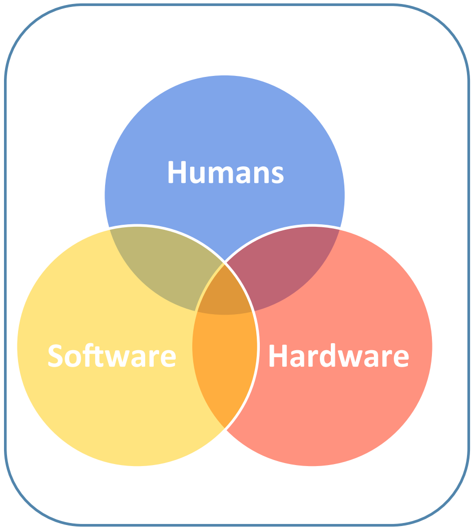
Set or arrangement of systems that results when independent and useful systems are integrated into a larger system that delivers unique capabilities

-DoD

System of Systems Engineering:

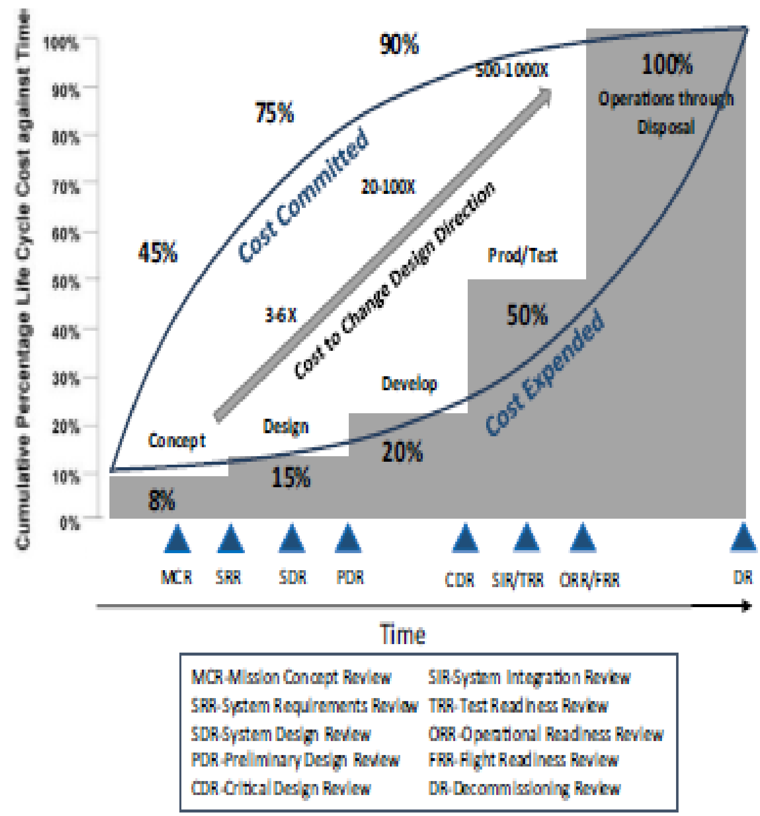
Planning, analyzing, organizing, and integrating the capabilities of a mix of existing and new systems into a SoS capability greater than the sum of the capabilities of the constituent parts.

Total System = SoS = Mission = Human + Hardware + Software



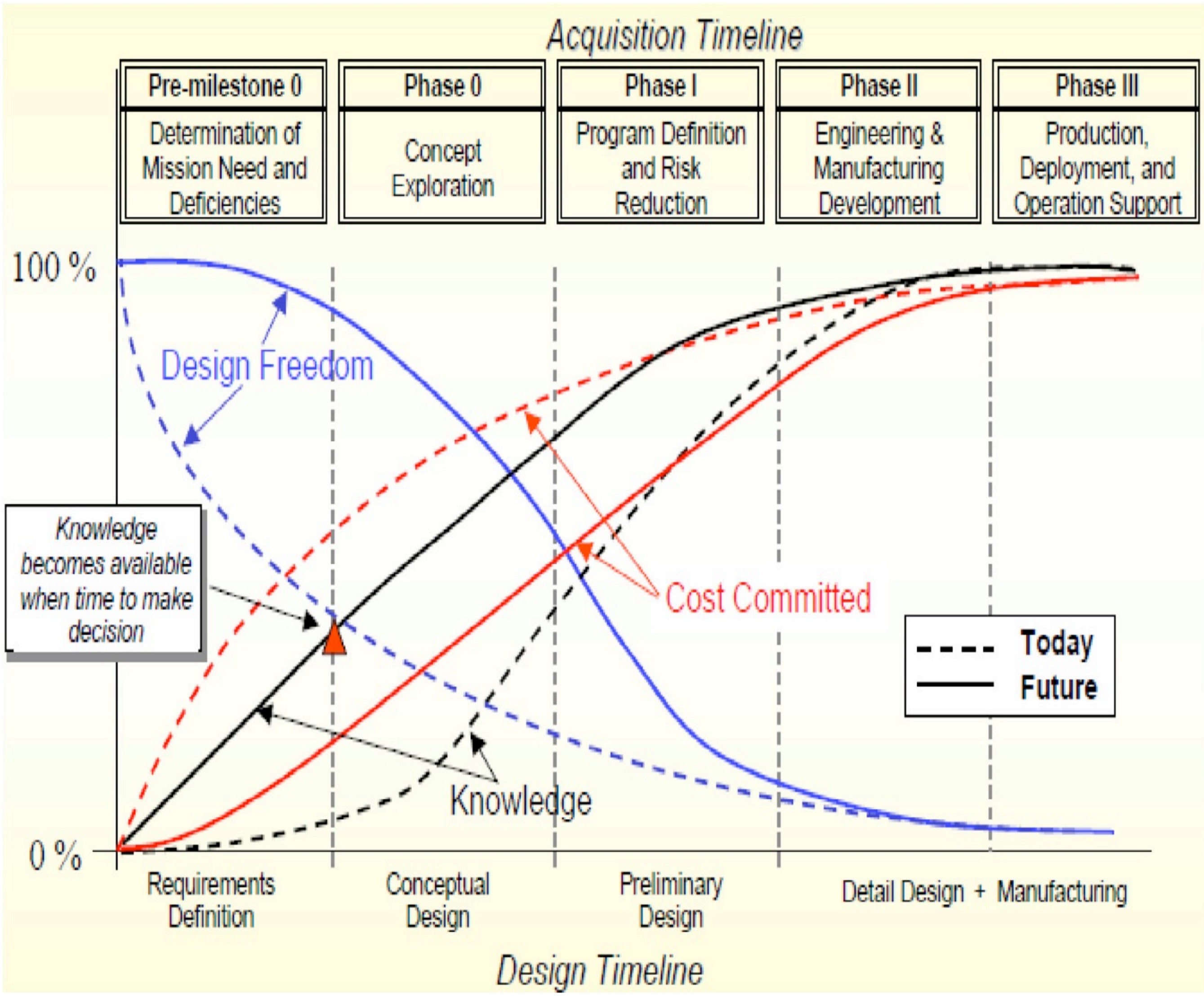
SoS Capability: A Paradigm Shift

- Focus shifting toward capability rather than on a system
- Top-down approach where capability is measured by how the SoS operates when integrated
- Design for performance to design for affordability



Life cycle cost impacts from early phase decision-making (adapted)

Paradigm Shift



Traditional vs. Paradigm Shift

Traditional	Paradigm Shift
Single-point design, manual, deterministic process	Dynamic parametric trade environment methods
Single-objective optimization	Multi-objective optimization
Single-discipline, disciplinary-centric analysis	Multidisciplinary approach (analysis, design, and optimization) based on more sophisticated and higher fidelity tools
Uneven distribution of knowledge and effort	Better representation of all disciplines in earlier lifecycle phases
Data driven process	Incorporation of probabilistic methods to quantify and assess risk
Design space exploration performed around one or a few concepts (point solutions)	Automation of resultant integrated design process
Reliance on historical data, usually full of many assumptions	Physics-based formulations, mainly for new concepts
Fixed design requirements and technology assumptions	Perform requirements exploration, technology infusion tradeoffs and concept down selections during conceptual design phases
Design for performance	Design for affordability and design for overall capability

History of HSI in Aerospace

DoD objectives:

(a) influence design for optimum combined human-machine system performance

(b) ensure that system conforms to the capabilities and limitations of the operator, maintainer, and other support personnel

(c) improve control of the total life cycle costs of the system, and

(d) ensure system safety and compliance with health standards

DoD instruction 5000.02

NASA objectives:

(e) contain lifecycle costs by bringing operations experience to design

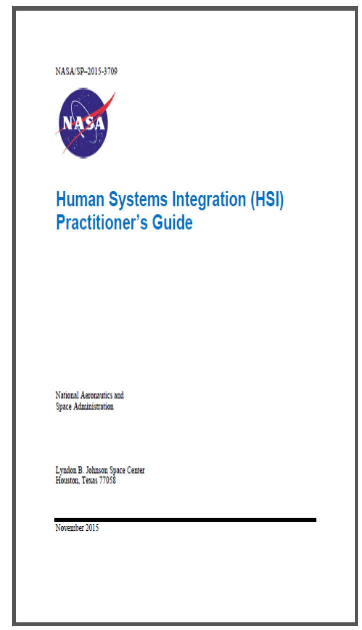
(f) development reducing manpower, skill demands, and training

NPR 8705.2B, 7123.1B, Practitioner's Guide

The HSI ERG promotes education and awareness in support of Inclusion and Innovation at JSC, with a focus on the HSI segment of JSC's workforce. The HSI Team works to support development, collaboration, recruitment, onboarding, and outreach activities for HSI employees in support of NASA's mission. The HSI ERG promotes cross-Directorate interaction toward a unified HSI vision, methodology, and implementation plan.

Chair: Rudy Balciunas
Co-chair: Shashi Gowda
Secretary: Lindsay Aitchinson
Communications Lead: Lucas Kinion
Recruiting: Christie Sauers
Professional Development: Jackelynne Silva-Martinez
Membership: Doug Wong

NASA/ SP-2015-3709, Human Systems Integration (HSI) Practitioner's Guide


NASA/SP-2015-3709

Human Systems Integration (HSI) Practitioner's Guide

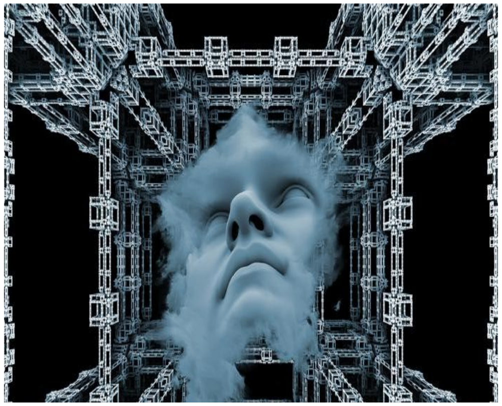
National Aeronautics and Space Administration

Lyndon B. Johnson Space Center
Houston, Texas 77058

November 2015

Human Factors:

- "Scientific discipline concerned with the understanding of interactions among humans and other elements of a system" [14].
- Discipline or process of acquiring and applying knowledge of human capabilities and limitations to the design and operation of system to enhance performance, safety, and user satisfaction.



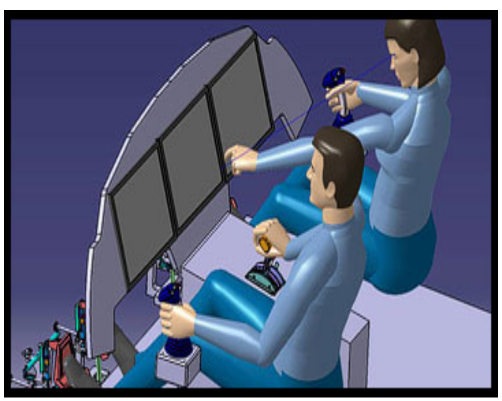
Human Factors Engineering:

- Application of a scientific body of knowledge about human strengths and weaknesses to the design of technology [15].
- It promotes successful human-machine integration.

Human Factors Engineering	Human Systems Integration
Focus: Design	Focus: Development Process
Science-based	Policy-based
Specific issues	Broad issues
Technical discipline	Process approach

Human-Centered Design:

- Performance based approach focused on making a design usable by the humans throughout the system's lifecycle (ISO 9241-210), where system refers to machines or automated systems [16].
- Focus of HFE, where user considerations are the focus throughout planning and design.

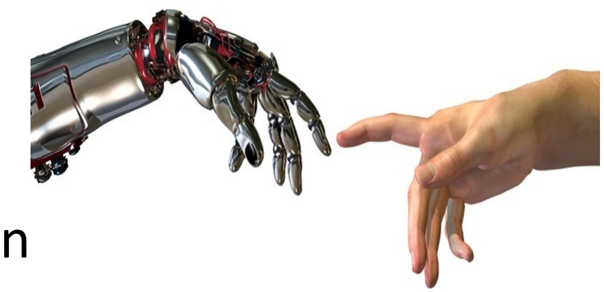


Human-Machine Interaction:

- Human-device interaction
- Info to the machine by the user: keyboard inputs, touch screen menu selections, and speech commands.
- Info to the user from the machine: includes displays, control panels, and auditory alarms.
- Interaction between the user and the system: dialog or interface between both.

Human Computer Interaction:

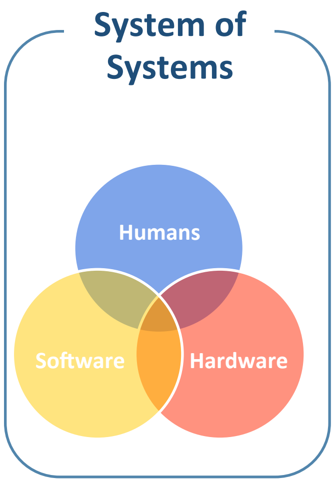
- Research field that studies and plans design of human centric computer systems. It is how people design, implement, and evaluate interactive computer systems in the context of users' tasks.
- Information acquired from HCI is used to make design interfaces or interactions [14]



Other Definitions:

- Human-Factor Integration: European version industry, UK Ministry of Defense)
- Human Systems Engineering: term once used by the Navy
- HSI-Hardware and Software Integration: occurs as part of the systems engineering integration phase
- At NASA, the Human System Risk Board also covers HSI design

System of Systems and HSI applied



- Human seen as separate part of the system
- Human is part of the system
- HSI terminology may be a transition

*Total Performance = equipment (SW/HW)*human performance*

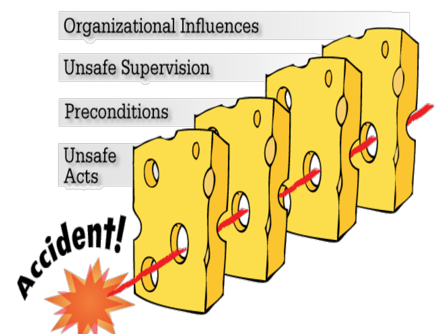
Humans = critical system of all safety critical systems

Human Error:

- Innate to humans
- Failure of a human action due to internal human failure mechanisms, sub-optimal human performance [22]

Human Failure:

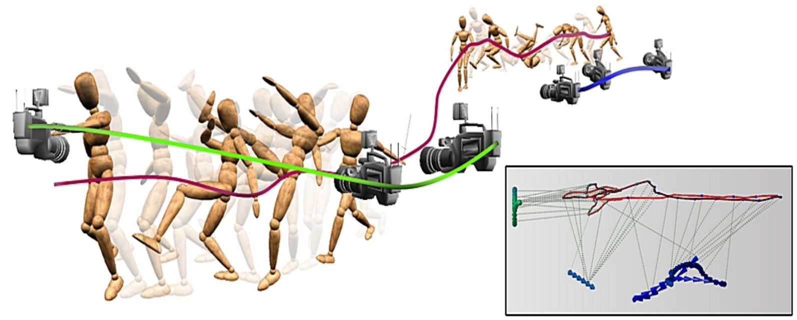
- Affects components (faults) and processes (disturbances) [23].
- Term used in Human Reliability Analysis (HRA) model



Human Error Classification:

The accident causation model, known as the Swiss cheese, explains that accidents take place due to a number of errors that have been occurring at different levels of the organizational hierarchy, making them inevitable to occur.
Human Factors Analysis and Classification System (HFACS)

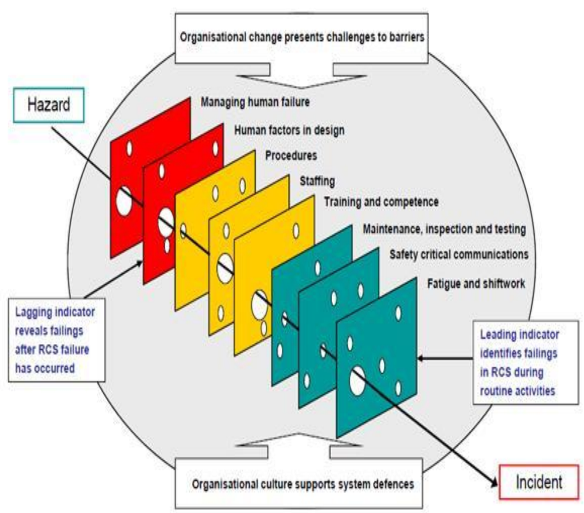
Human Action



- Affect process stability or availability of technical systems
- Classifications:
  - **Primary human actions:** front line actions through which humans are in direct interface with a process stability or availability, hardware, or software.
  - **Secondary human actions:** supervision, work planning, procedure writing, training, quality control, quality assurance, inspections, analysis and others that assist and prepare primary actions.
  - **Role of human action in system actuation:** depends on the design of the installation, ex: where there is no automated signals for the machine to start, human actuation is necessary.

Human Error Techniques

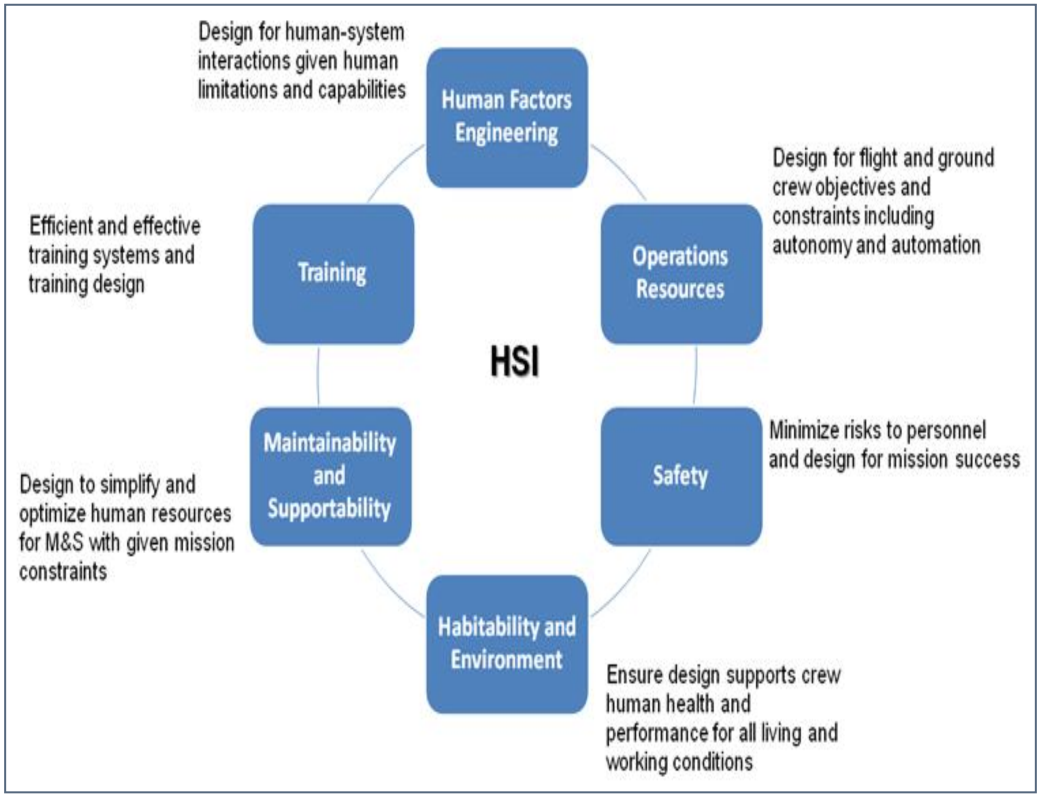
- NPR 8705.2B ''Human Rating Requirements"
- Probabilistic Risk Assessment (PRA)
- Human Reliability Analysis (HRA)
- SMEs



HRA tools used in nuclear industry that can be used in aerospace:

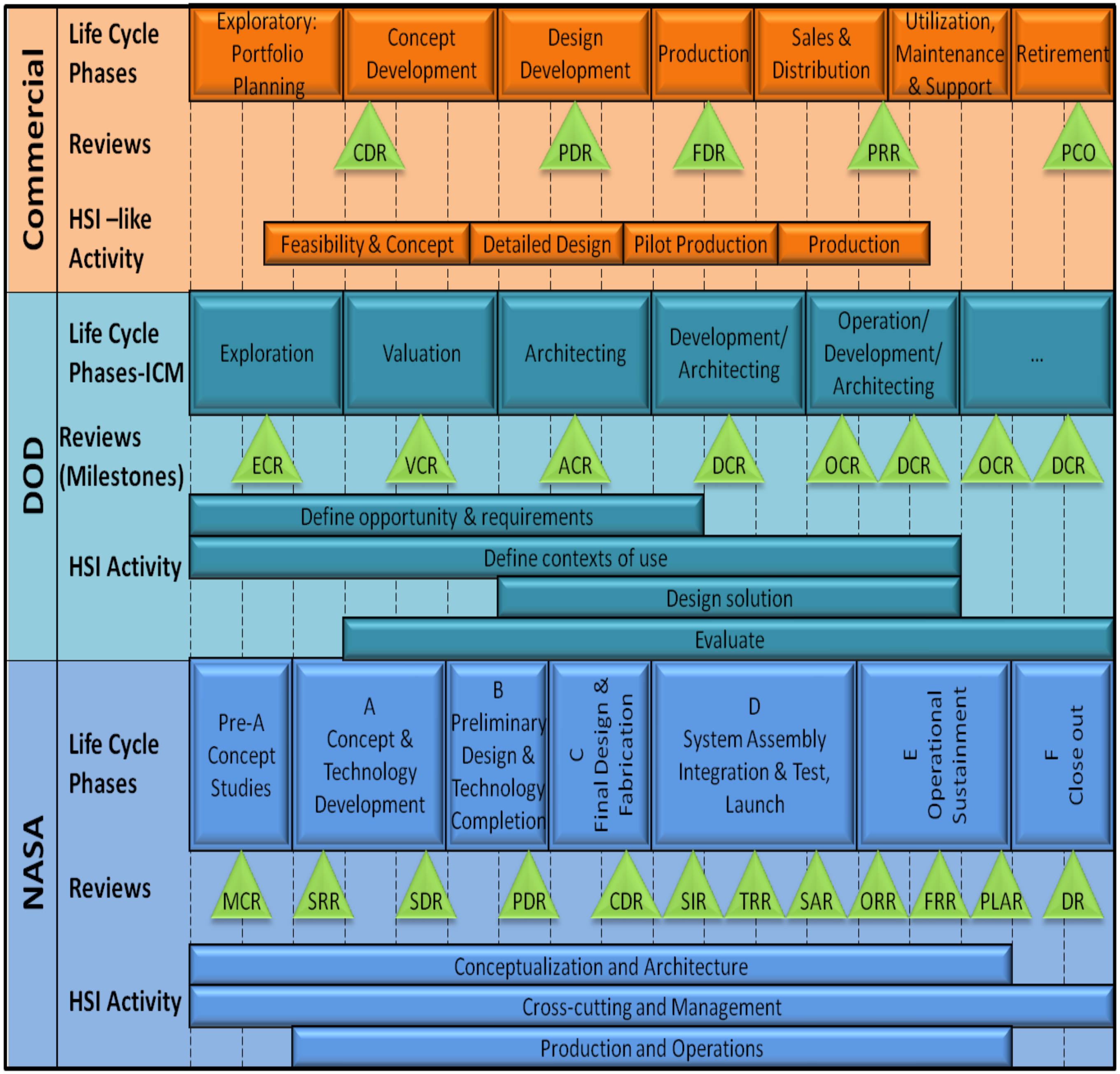
- Human error assessment and reduction technique (HEART)
- Cognitive reliability and error analysis method (CREAM)
- Absolute probability Judgements (APJ)
- INTENT
- Connectionism assessment of human reliability (CAHR)

HSI Domains at the DoD   HSI Domains at NASA



Comparison of DoD and NASA HSI domains

DOD HSI Domains	NASA HSI Domains	Comments
Human Factors Engineering	Human Factors Engineering	---
System Safety	Safety	---
Health Hazards	---	It is accounted within NASA Habitability and Environment
Personnel Survivability	Maintainability and Supportability	---
Manpower	---	The DoD deals with having enough people to support the tasks. They have a higher number of personnel than crewmembers in space missions, hence NASA does not use it.
Personnel	---	The DoD provides training as the expectation is no prior skills. At NASA, it is assumed that personnel came in with prior knowledge and have the skills to perform the work (accounted within training).
Training	Training	
Habitability	Habitability and Environment	Includes medical, crew health and countermeasures, and physiology
---	Operations Resources	NASA specializes in autonomy/automation of systems interacting with crewmembers



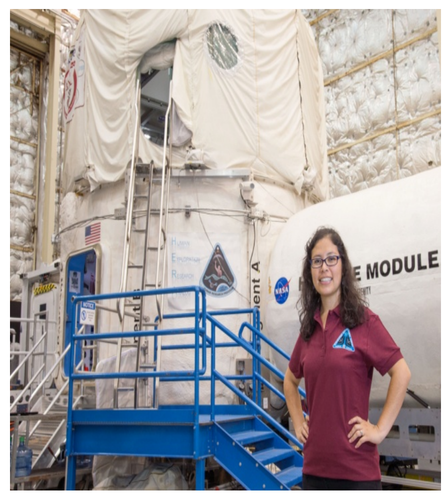
HSI activities during reviews and lifecycle phases for commercial products, DoD, and NASA missions
Ref.: ISO/IEC/IEEE 15288, DoD HSI in the System Development Process, NASA/SP-2015-3709

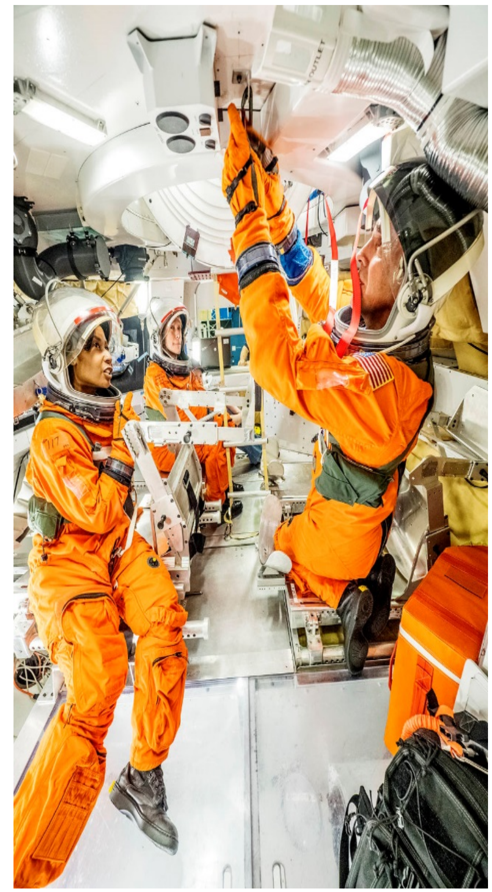
HSI Practitioner's Guide (NASA/SP-2015-3709)

- **Conceptualization and Architecture:** ConOps, HSI requirements, human prototypes, human assessments and inputs to technology maturation
- **Cross-cutting and Management:** program or product's HSI plan, trade study reports, MOE, MOP, HSI domain risks, lessons learned, TPMs
- **Production and Operations:** Operations concept, human in the loop testing, operations/logistics/handling documents review, and monitoring of human performance.

HSI Evaluation Methods

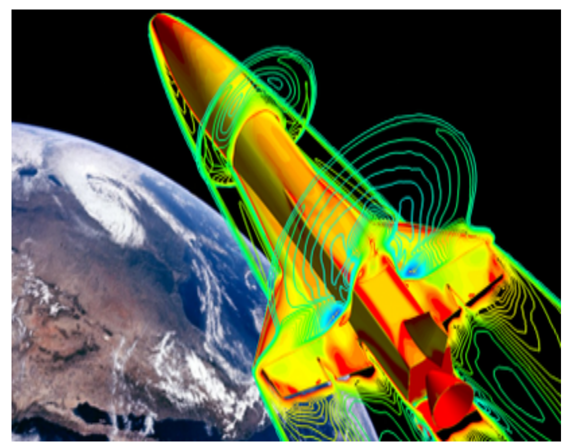
- Human-in-the-loop evaluation
- Usability evaluation
- Workload evaluation
- Simulations
- Decision making
  - Alternatives, outcomes, preferences





Future Work

- High-fidelity, physics-based analyses early in the design process through advanced concepts, multidisciplinary design, complex tradeoffs, and shortened design cycle
- Modeling and simulation need to be increased in HSI activities
- Humans introduce unexpected dependencies into a system, capable of decision making; collection of more factual data is needed to add to modeling tools to decrease their randomness



Conclusions

- HSI ensures the design of a mission, project, or product systems are centered on the needs, capabilities, and limitations of the human.
    - Human-system requirements and V&V method
- Need to understand overall role of humans within a technological setting
    - Plan, design, train, and operate for future space missions accordingly
- HSI enables the integration of human considerations throughout the lifecycle of our missions.

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