Implementation of Human Systems Integration in a Mission Lifecycle

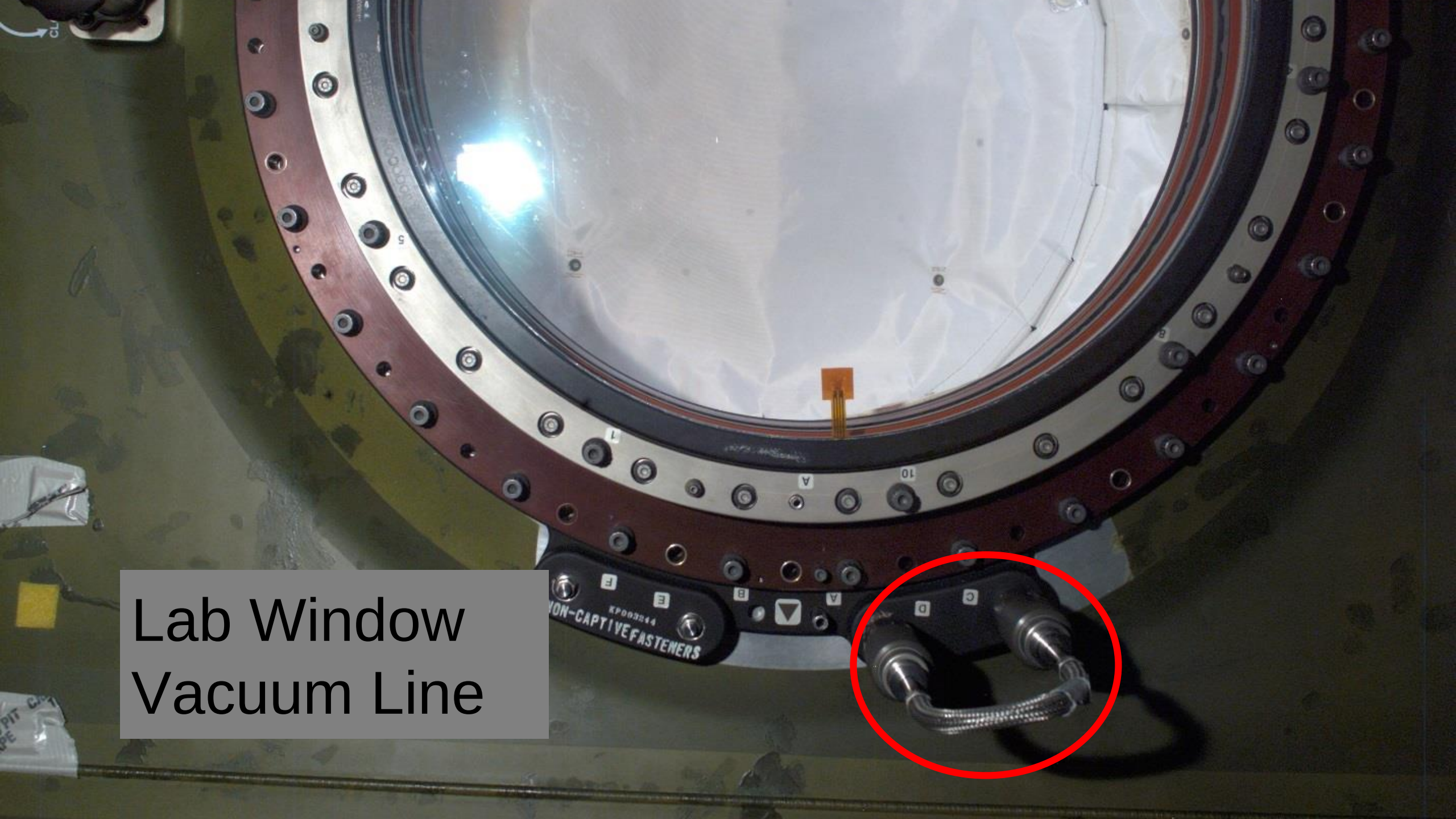
Human Systems Integration Working Group

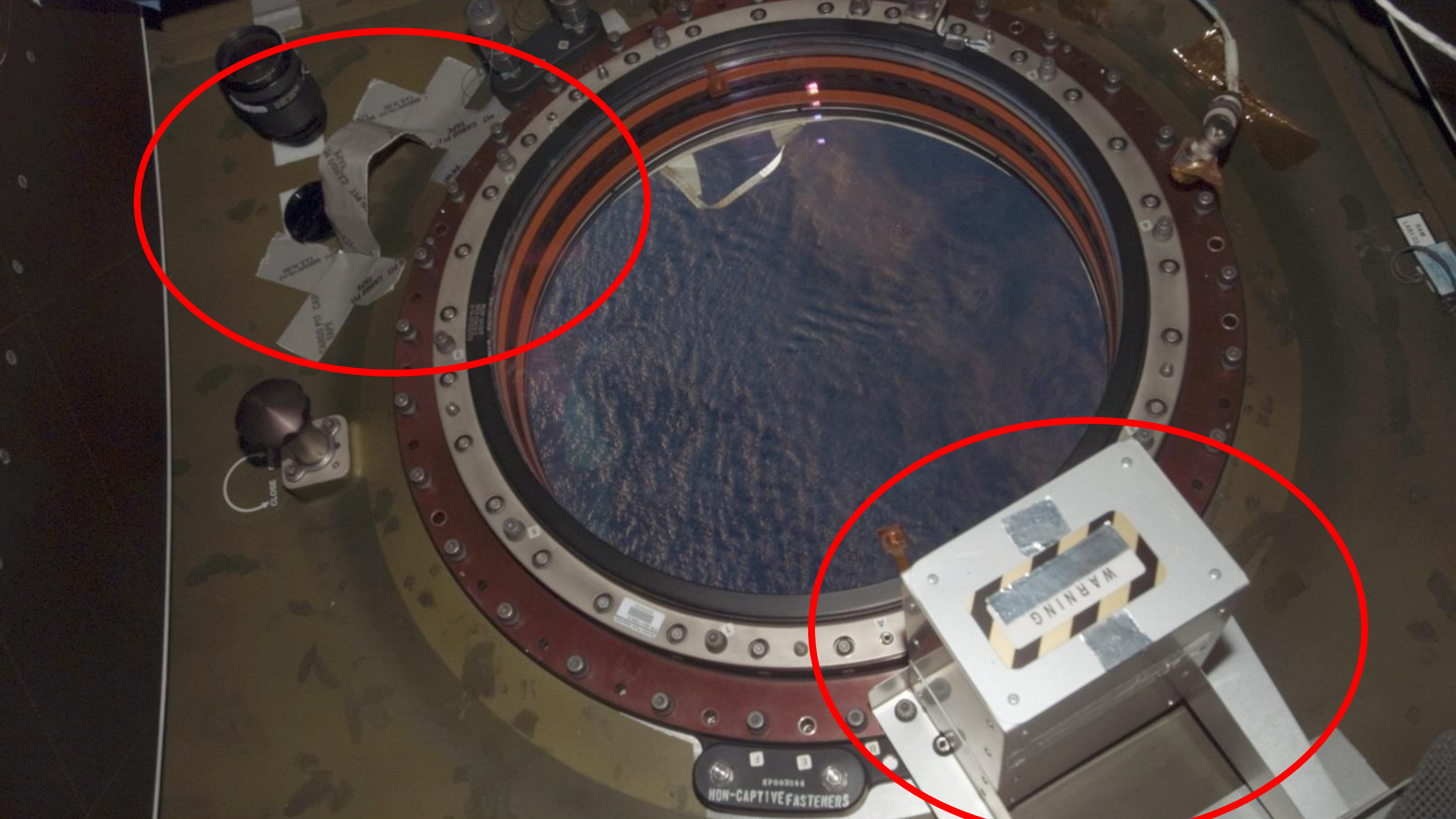
Date: October 15, 2020

Jackelynne Silva-Martinez, NASA Johnson Space Center

Outline

- Why Human Systems Integration?
- What is HSI? – An Overview
- HSI Activities in a Mission's Lifecycle
- Program/Mission HSI Plan
- NASA HSI Domains
- HSI Working Group
- Conclusion


Lab Window
Vacuum Line


WARNING
NON-CAPTIVE FASTENERS

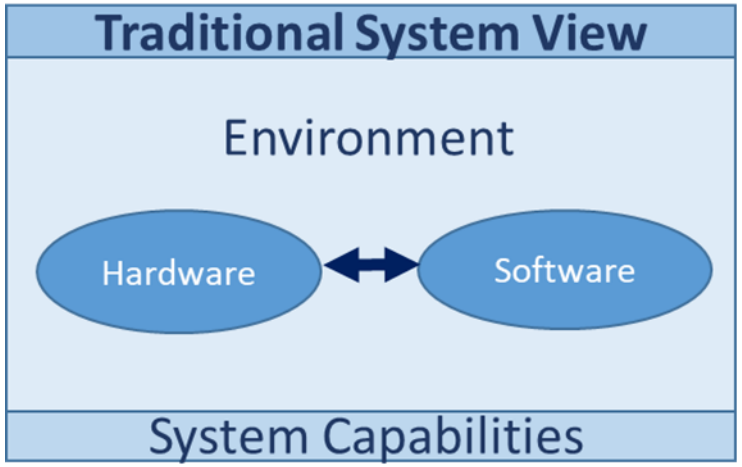
Carbon Dioxide Removal Assembly

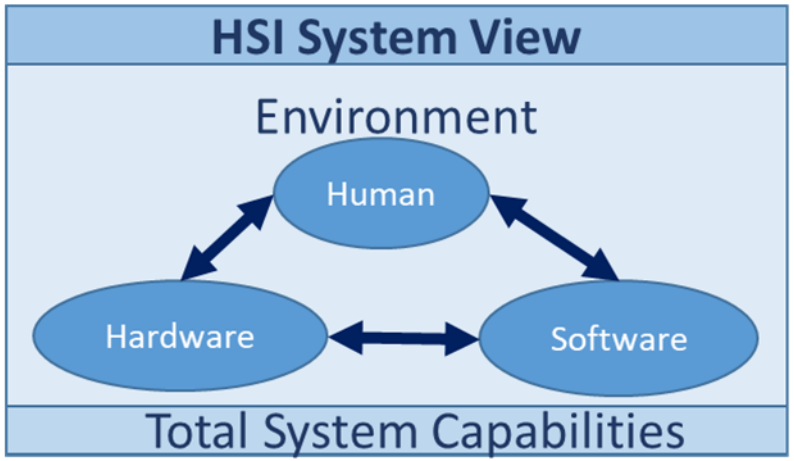
Robonaut on ISS

HSI Overview

HSI Definition per NPR 7123.1C NASA Systems Engineering Processes and Requirements

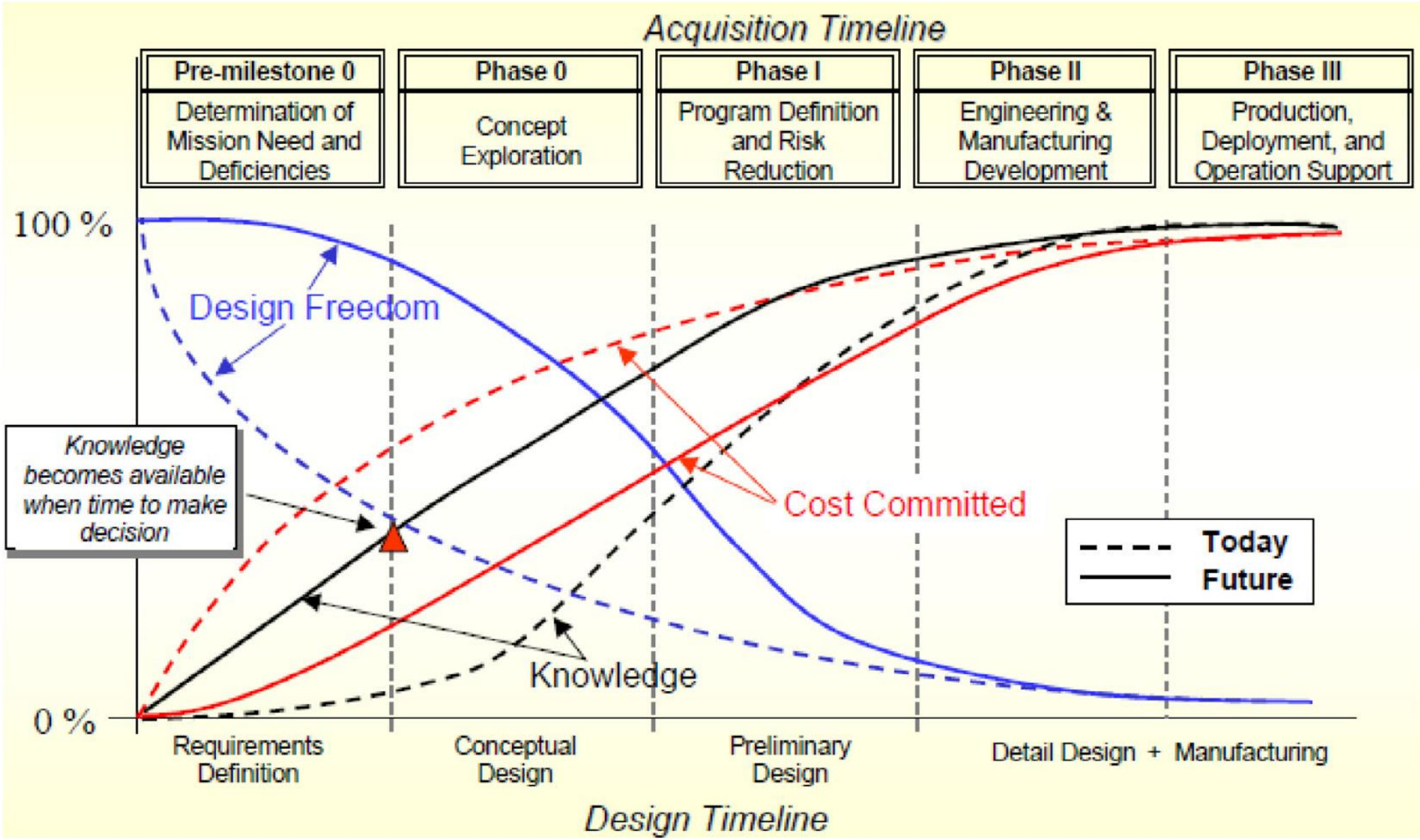
An interdisciplinary and comprehensive management and technical process that focuses on the integration of human considerations into the system acquisition and development processes to enhance human system design, reduce lifecycle ownership cost, and optimize total system performance. Human system domain design activities associated with operations, training, human factors engineering, safety, quality, maintainability and supportability, habitability, and survivability are considered concurrently and integrated with all other systems engineering design activities.





Human in HSI refers to all personnel involved in a given system

System of System Capability: A 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

System of Systems

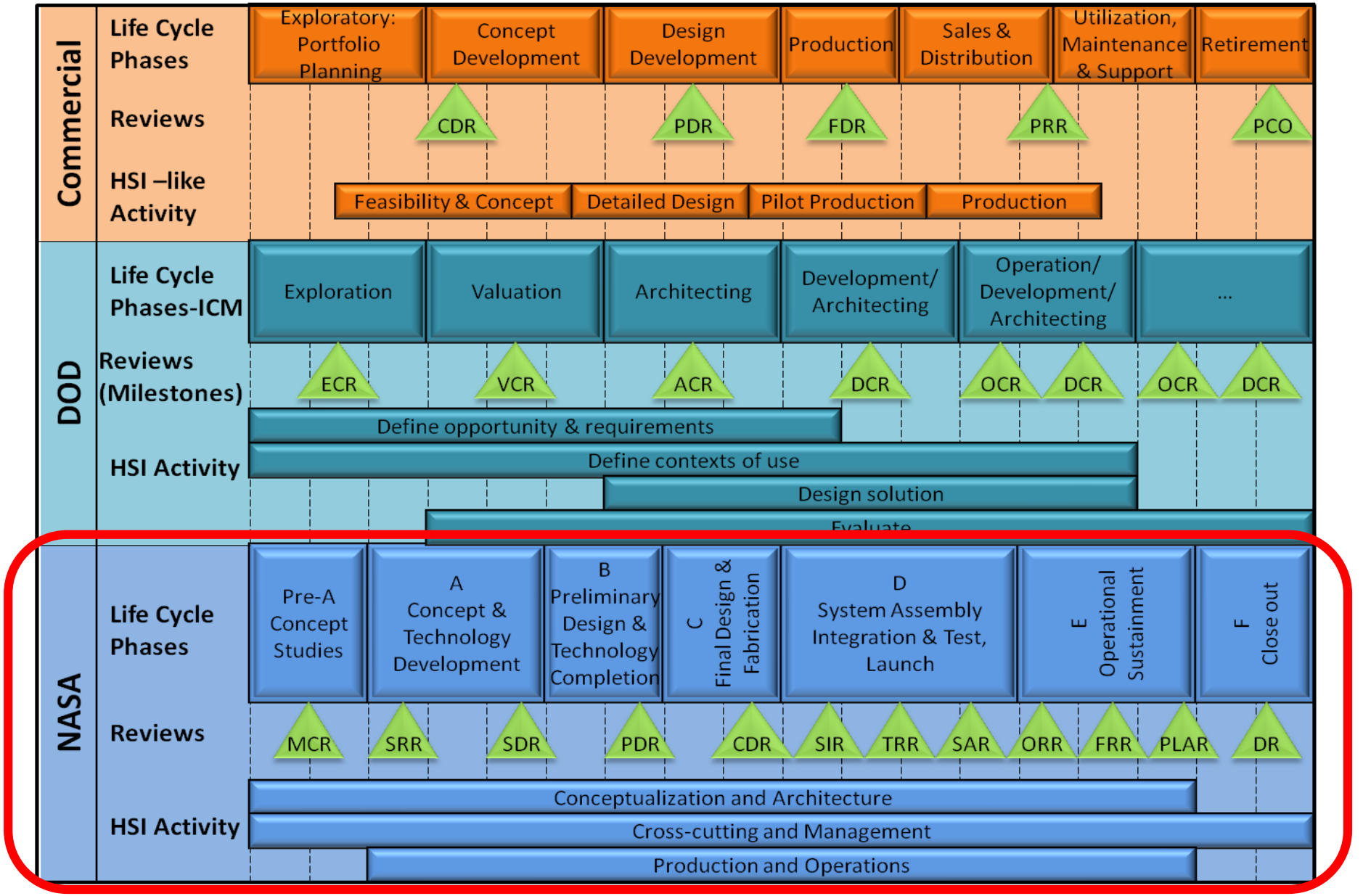
System of Systems Engineering:

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

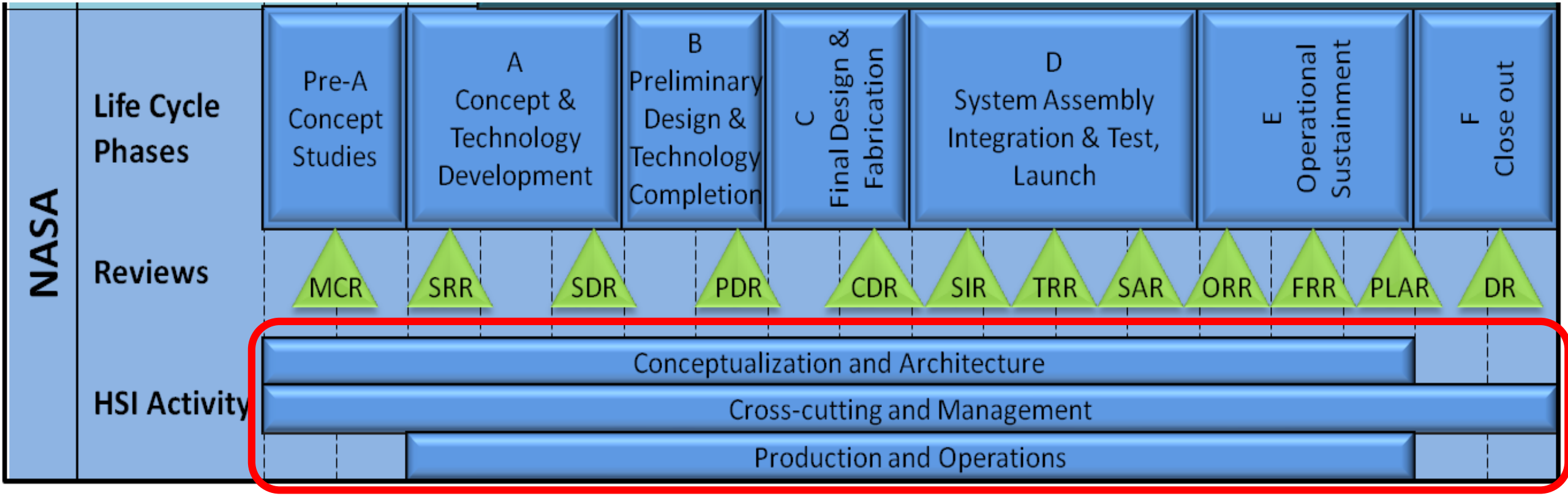
$$Total\ System = SoS = Mission = Human + Hardware + Software$$

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

Humans = critical system of all safety critical systems



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



- **Conceptualization and Architecture:** ConOps, HSI requirements, human prototypes, human assessments and inputs to technology maturation

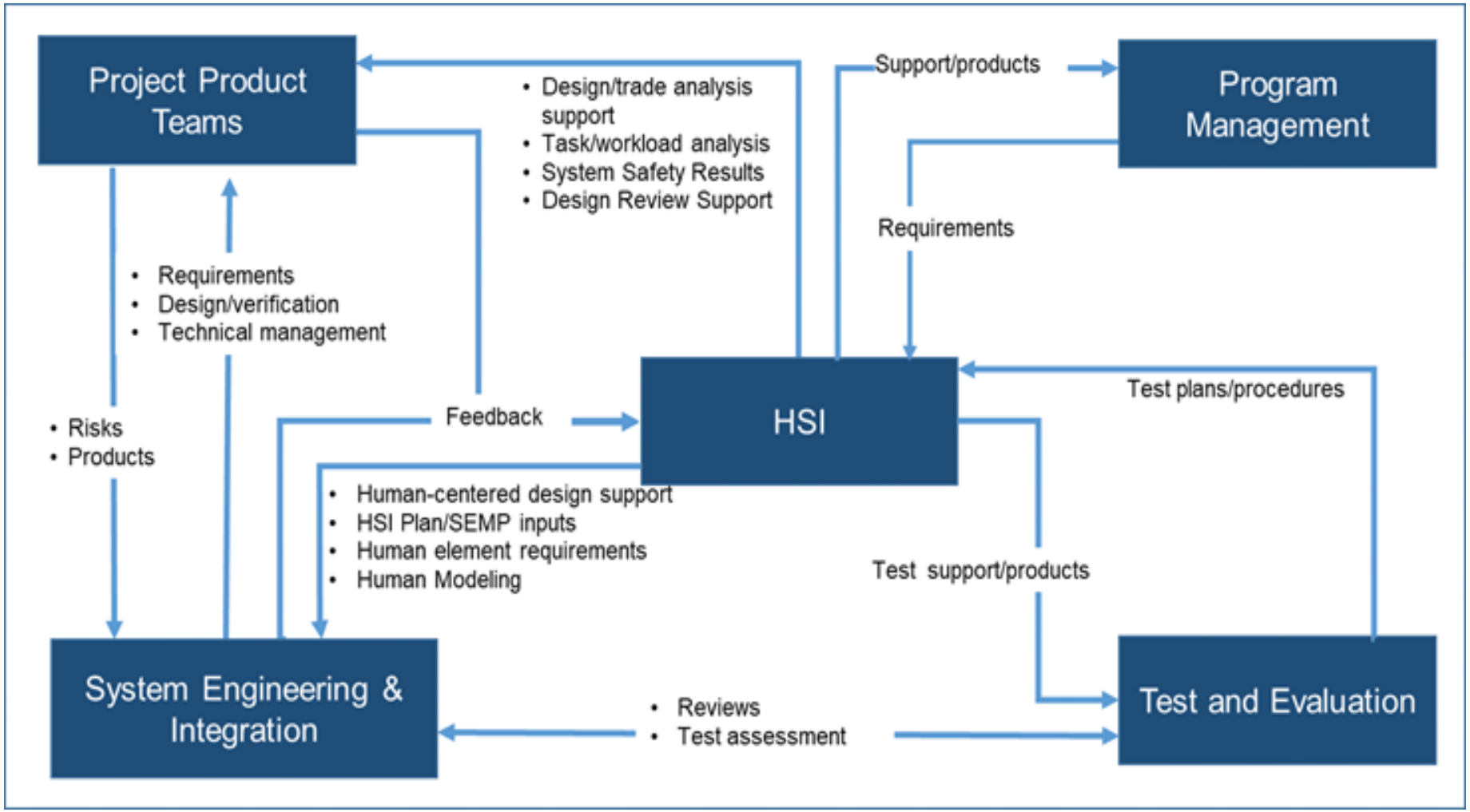
- **Cross-cutting and Management:** program or product's HSI plan, trade study reports, MOE, MOP, HSI domain risks, lessons learned, TPMs

- **Production and Operations:** Operations concept, human in the loop testing, operations/logistics/handling documents review, and monitoring of human performance

HSI Activities, Products, Risk Mitigation by Lifecycle Phase

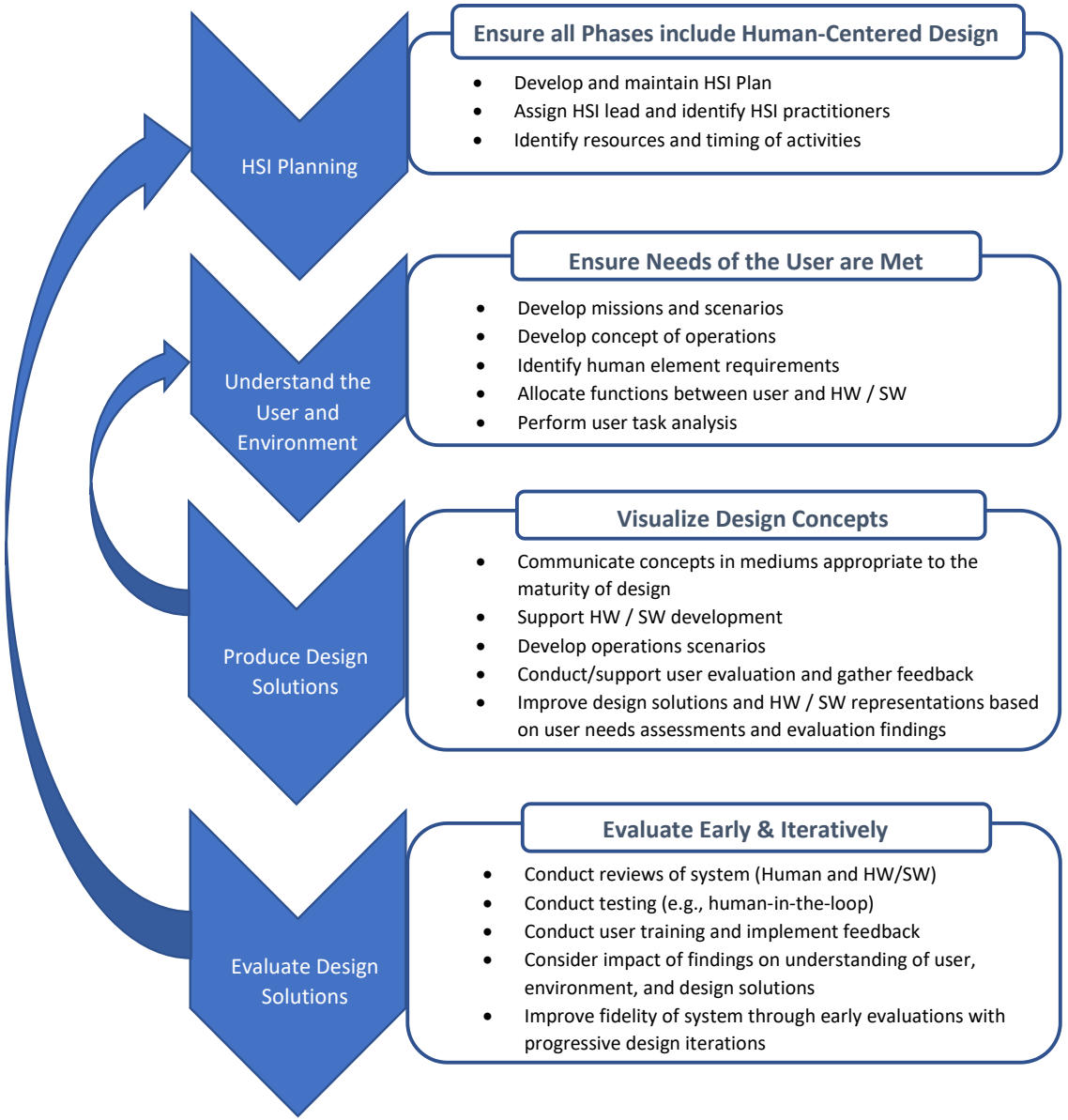
Life Cycle Phase	Phase Description	Activity, Product, or Risk Mitigation
Pre-Phase A	Concept Studies	• ConOps (Preliminary—to include training, maintenance, logistics, etc.)
Phase A	Concept & Technology Development	• HSI Plan (Baseline) • ConOps (Initial) • HSI responsible party(ies) and/or Team identified before SRR • Develop mockup(s) for HSI evaluations • Crew Workload Evaluation Plan • Function allocation, crew task lists • Validation of ConOps (planning)
Phase B	Preliminary Design & Technology Completion	• HSI Plan (update) • ConOps (Baseline) • Develop engineering-level mockup(s) for HSI evaluations • Define crew environmental and crew health support needs (e.g., aircraft flight decks, human space flight missions) • Assess operator interfaces through task analyses (for, e.g., aircraft cockpit operations, air traffic management, spacecraft environments, mission control for human space flight missions) • HITL usability plan • Human-Rating report for PDR
Phase C	Final Design & Fabrication	• HSI Plan (update) • First Article HSI Tests • Human-Rating report for CDR
Phase D	System Assembly, Integ. & Test, Launch & Checkout	• Human-Rating report for ORR • Validation of human-centered design activities • Validation of ConOps
Phase E	Operations & Sustainment	• Monitoring of human-centered design performance
Phase F	Closeout	• Lessons Learned report

Systems Engineering – HSI Interaction



System optimization happens in an integrated fashion and not components that have been independently optimized

Systems Engineering – HSI Interaction

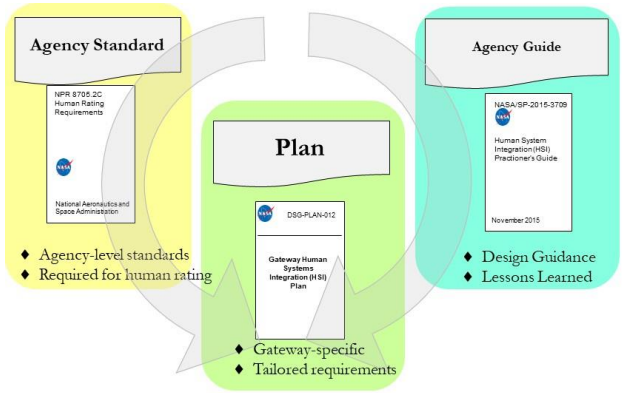


In both, Systems Engineering and HSI, testing is critical

HSI Plan

Why do we have the HSI Plan?

- *NPR 7123.1C NASA Systems Engineering Processes and Requirements*, and *NPR 8705.2C Human-Rating Requirements for Space Systems* require the use of an HSI Plan and the formation of an HSI Team
- HSI Plan content is guided by the NASA/SP-2015-3709 Human Systems Integration Practitioner's Guide



Sample HSI Plan Table of Contents

1.0 Introduction (Purpose, Scope, Definitions)
2.0 Documents (Applicable, Reference)
3.0 HSI Objectives
    3.1 System Description
    3.2 HSI Relevance
4.0 HSI Strategy
    4.1 HSI Strategy Summary
    4.2 HSI Domains
5.0 Requirements, Organization, and Risk Management
    5.1 HSI Requirements
    5.2 HSI Organization, Roles, and Responsibilities
    5.3 HSI Issues ad Risks Processing
6.0 HSI Implementation
    6.1 HSI Implementation Summary
    6.2 HSI Products
    6.3 HSI Plan Update
Appendices

What is contained in the HSI Plan?

- Describes planned HSI methodology, tools, activities, and deliverables
- Points to location of known HSI issues and concerns, and explains how resolutions will be addressed
- Defines HSI organizational roles and responsibilities

NASA HSI Domains Overview

Design for human-system interactions given human limitations and capabilities

Design for flight and ground human objectives and constraints including autonomy and automation

Minimize risks to personnel and design for mission success

Ensure design supports human health and performance for all living and working conditions

Design to simplify and optimize human resources for M&S with given mission constraints

Efficient and effective training systems and training design

NASA HSI Domains

Domain	Definition	Examples of Expertise

Human Factors Engineering (HFE)	• Designing hardware and software to optimize human well-being and overall system safety, performance, and operability
	• Designing with an emphasis on human capabilities and limitations as they impact, and are impacted by system design across mission environments and conditions (nominal, contingency, and emergency)
	• Supporting robust integration of all humans interacting with a system throughout its life cycle
	• HFE solutions are guided by three principles:
	  • Systems' demands shall be compatible with human capabilities and limitations
	  • Systems shall enable utilization of human capabilities in non-routine and unpredicted situations
	  • Systems shall tolerate and recover from human errors
		• Task analysis
		• Human performance measures
		  ○ Workload
		  ○ Usability
		  ○ Situation awareness
		• HFE design and analysis
		  ○ Anthropometry and biomechanics
		  ○ Human functions
		  ○ Habitat architecture
		• HITL evaluation
		• Human error analysis
		• Human-system interfaces

NASA HSI Domains

Domain	Definition	Examples of Expertise
Operations Resources	• Considerations and resources required for operations planning and execution • Operability and human effectiveness for flight and ground personnel to drive system design and development phases, as well as trades for function allocation, automation, and autonomy	• Operations process design for both ground and flight personnel • Human/machine resource allocation • Mission operations • Resource modeling and complexity analysis • Flight operations • Procedure development • Flight crew time • Staffing/qualifications analysis
Maintainability and Supportability	• Designing to simplify maintenance and optimize human resources, spares, consumables, and logistics • These are essential aspects due to limited time, access, and distance for space missions	• In-flight maintenance and housekeeping • Ground maintenance and assembly • Sustainability and logistics

NASA HSI Domains

Domain	Definition	Examples of Expertise
Habitability and Environment	• External and internal environment considerations for human habitat and exposure to natural environment • Includes factors of living and working conditions necessary to sustain the morale, safety, health, and performance of the user population, which directly affect personnel effectiveness	• Environmental health • Radiation health • Toxicology • Nutrition • Acoustics • Architecture • Human health and countermeasures • Extravehicular physiology • Medical concerns • Lighting
Safety	• Safety factors ensure the execution of mission activities with minimal risk to personnel • Mission success includes returning the flight crew following completion of mission objectives and maintaining the safety of ground personnel	• Safety analysis • Reliability • Quality assurance • Factors of survivability • Human rating analysis • Hazard analysis
Training	• Design training program to simplify the resources that are required to provide personnel with requisite knowledge, skills, and abilities to properly operate, maintain, and support the system	• Instructional design • Training facility development • On-board training (OBT)

Requirements Mapped to NASA HSI Domains

It is recommended to create a mapping of HSI Domains to specifications or requirement documents to ensure all 6 HSI Domains are being addressed. Content, details, and context must be reviewed to:

- Determine if there are possible gaps of lack of HSI within the design
- Identify groups of collaboration so as not to duplicate efforts or going in different directions

HSI Working Group

- Provides a forum for discussion of HSI related topics with stakeholders from different NASA HSI Domains across the Program. These discussions result in integrated HSI recommendations presented to the NASA Technical Authorities and Program management to inform their decisions.
- Follows policies defined in *NPR 7123.1C NASA Systems Engineering Processes and Requirements*, and *NPR 8705.2C Human-Rating Requirements for Space Systems*
- Defines and manages Program/Mission HSI activities, coordination and development of HSI driven recommendations regarding program requirements, design, and implementation
- Develops and maintains identified HSI risks
- Represents HSI interests in trade studies, technology down selects, early phase simulations, model development, within others

A guide to establishing a HSI WG is available

What is needed for an HSI WG?

- HSI WG Charter
- Stakeholders
- Presentations template
- Recommendations derived from discussion topics and submitted to Program/Technical authorities
- Watch List
- Action log
- Logistics

HSI WG Charter

- Purpose
- Scope
- Membership
- Meeting frequency
- Responsibilities
- Decision authority

HSI WG Representatives

- The HSI Plan defines roles and responsibilities within the Program/Project
- HSI responsibilities cross organizational lines and must include participants across HSI Domains and Program/Project functions
- Example:

HSI Domains Representatives • Human Factors Engineering • Training • Safety • Maintainability and Supportability • Operations Resources • Habitability and Environment	Systems Engineering Leads • System Leads • Subsystem Leads • Component Leads
Directorate/Department Representatives • Operations • Engineering • Safety and Mission Assurance	Program Leads Project Leads
Provider Representatives	International Partners
Cross-Program Representatives	Ad-hoc Members

Conclusion

- HSI is a process by which human capabilities and limitations are effectively and affordably integrated with system design and development
  - Human systems requirements, and their verification and validation prior to flight

- Need to understand overall role of humans within a technological setting
  - Plan, design, test, train, and operate for future space missions accordingly
  - HSI enables better error management

- HSI enables the integration of human considerations throughout the lifecycle of our missions
  - Applies across all systems (system of systems)
  - Reduces total system life-cycle costs

References

- Human Systems Integration: Process to Help Minimize Human Errors, a Systems Engineering Perspective for Human Space Exploration Missions, Journal REACH - Reviews in Human Space Exploration. V2, 8-23, 2016, Published by Elsevier.
- NPR 7123.1B NASA Systems Engineering Processes and Requirements
- NPR 8705.2C Human-Rating Requirements for Space Systems
- NASA/SP-2015-3709 Human Systems Integration (HSI) Practitioner's Guide https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20150022283.pdf
- SEBoK Systems of Systems (SoS). Guide to the systems engineering body of knowledge, 2015. Retrieved from: http://sebokwiki.org/wiki/Systems_of_Systems_(SoS).
- International Council on Systems Engineering: INCOSE. Systems Engineering Handbook Volume 3.1 Appendix M, 2010.
- National Research Council: NRC. Human-System Integration in the System Development Process. A New look: The National Academies Press, Washington, DC; 2008.
- *JSC Human Systems Integration Employee Resource Group*
- *INCOSE HSI Working Group*