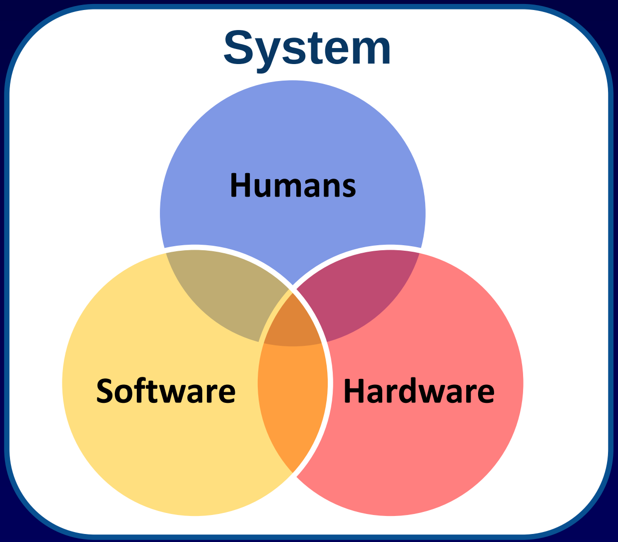
Introduction to Human Systems Integration (HSI)



Presented by:
Elton G. Witt

Agenda

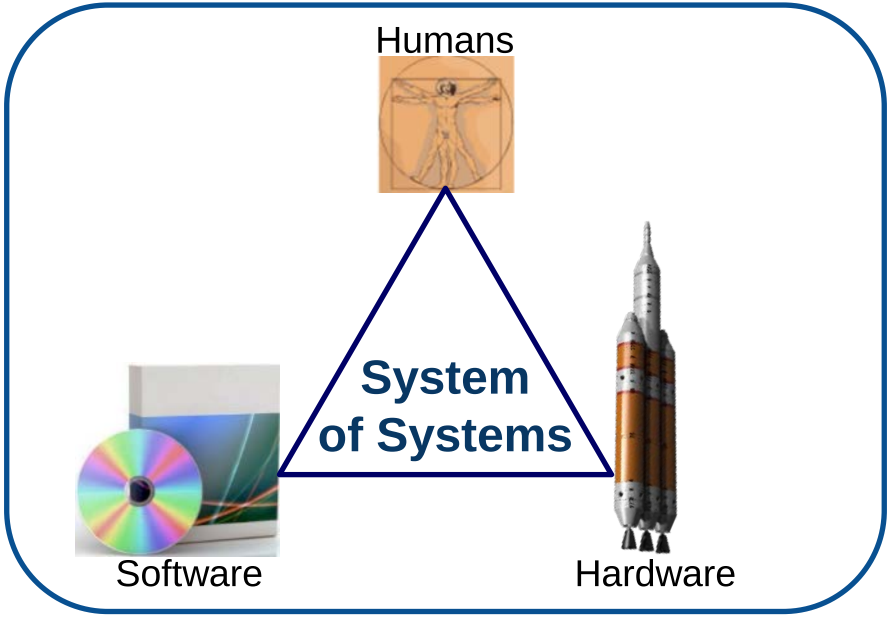
- **Section I: Introduction to Human Systems Integration**
  - Provides an overview of Human Systems Integration (HSI), cost and return on investment, HSI domains, how HSI fits into the NASA organization structure, HSI roles and comparison of HSI to Human Factors Engineering (HFE).

- **Section II: HSI in the Systems Engineering & Integration Lifecycle**
  - Overview of HSI and Systems Engineering, comparison of DoD and SE Lifecycle, HSI Mandates (DoD and NASA), and keys to a successful HSI Practice.

- **Section III: Implementing HSI in the NASA Environment**
  - Introducing the HSI Practitioner's Guide and content, final exercise, and a few words about the future of HSI @ NASA.

Section I

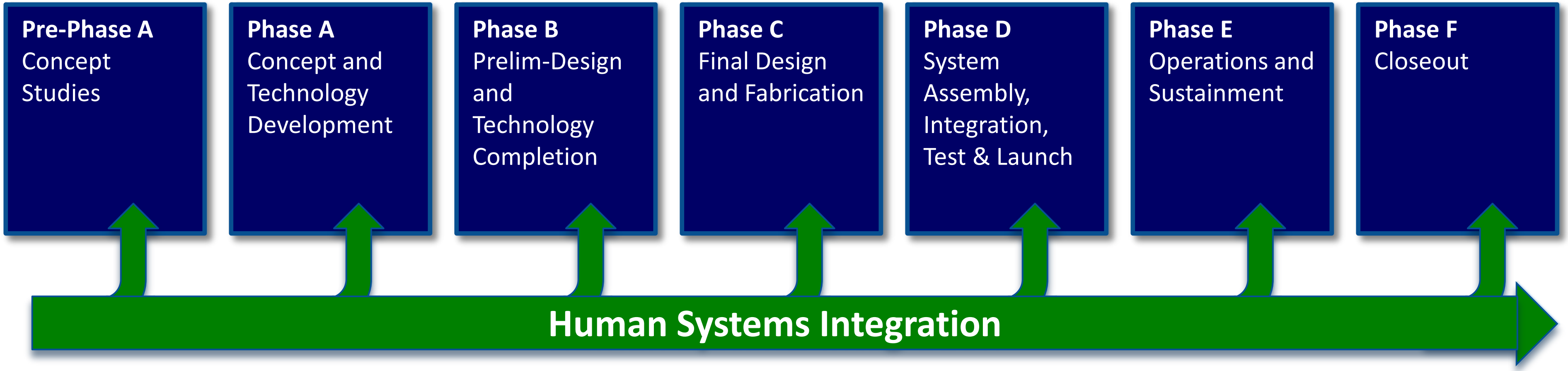
Introduction to Human Systems Integration



HSI = a "total systems" approach: humans in the system must be considered

What is Human Systems Integration?

- A system is defined as a complex engineering project undertaken to meet the needs of a mission or operational goal.
- Human Systems Integration is a ***process*** that ensures human capabilities and limitations are effectively considered in system design and development
- This reduces lifecycle costs by ensuring that designers consider operational costs, particularly those associated with users and maintainers of a system
- It places human concerns on par with other aspects of system design



These are the phases of a program's or project's engineering lifecycle as defined in NPR 7123.1B "System Engineering Processes and Requirements"

Formal HSI Definition from NPR 7123.1B

Human Systems Integration:

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 life-cycle ownership cost, and optimize total system performance.

Benefit Clause

NPR 7123.1B defines the system as
hardware + software + humans

Ref: *NPR 7123.1B, System Engineering Processes and Requirements*

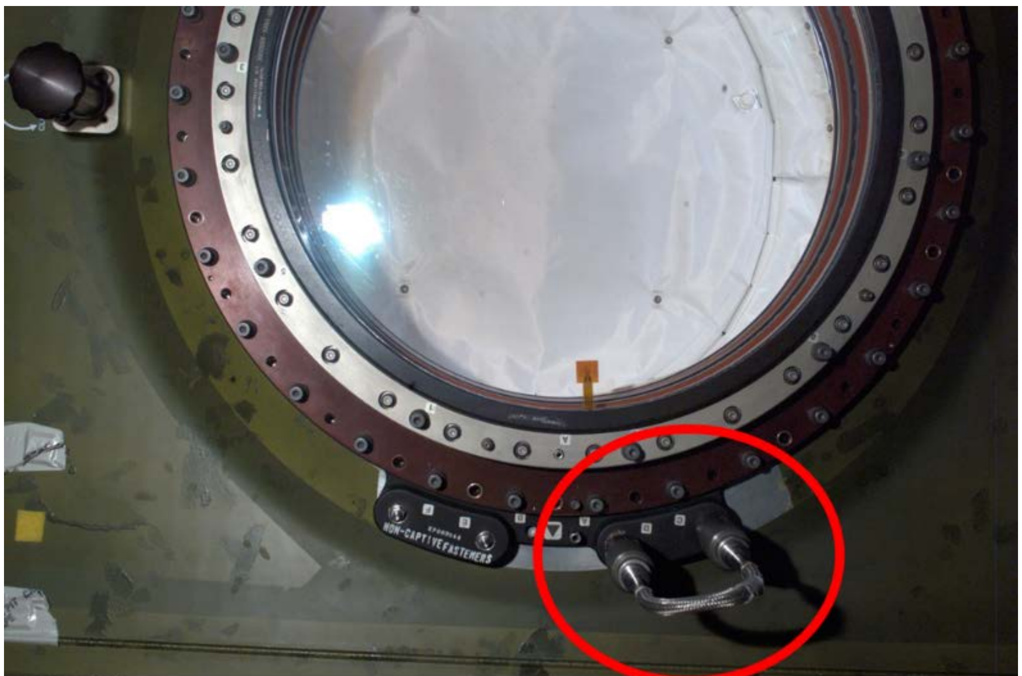
HSI Definition: INCOSE

Human Systems Integration brings human-centered disciplines and concerns into the SE process to improve the overall system design and performance.

Thus, it is clear that the human is an element of every system, so all systems benefit from HSI application.

A Quick Example: Lab Window Vacuum Line

If it looks like a handhold, the crew will use it as a handhold.



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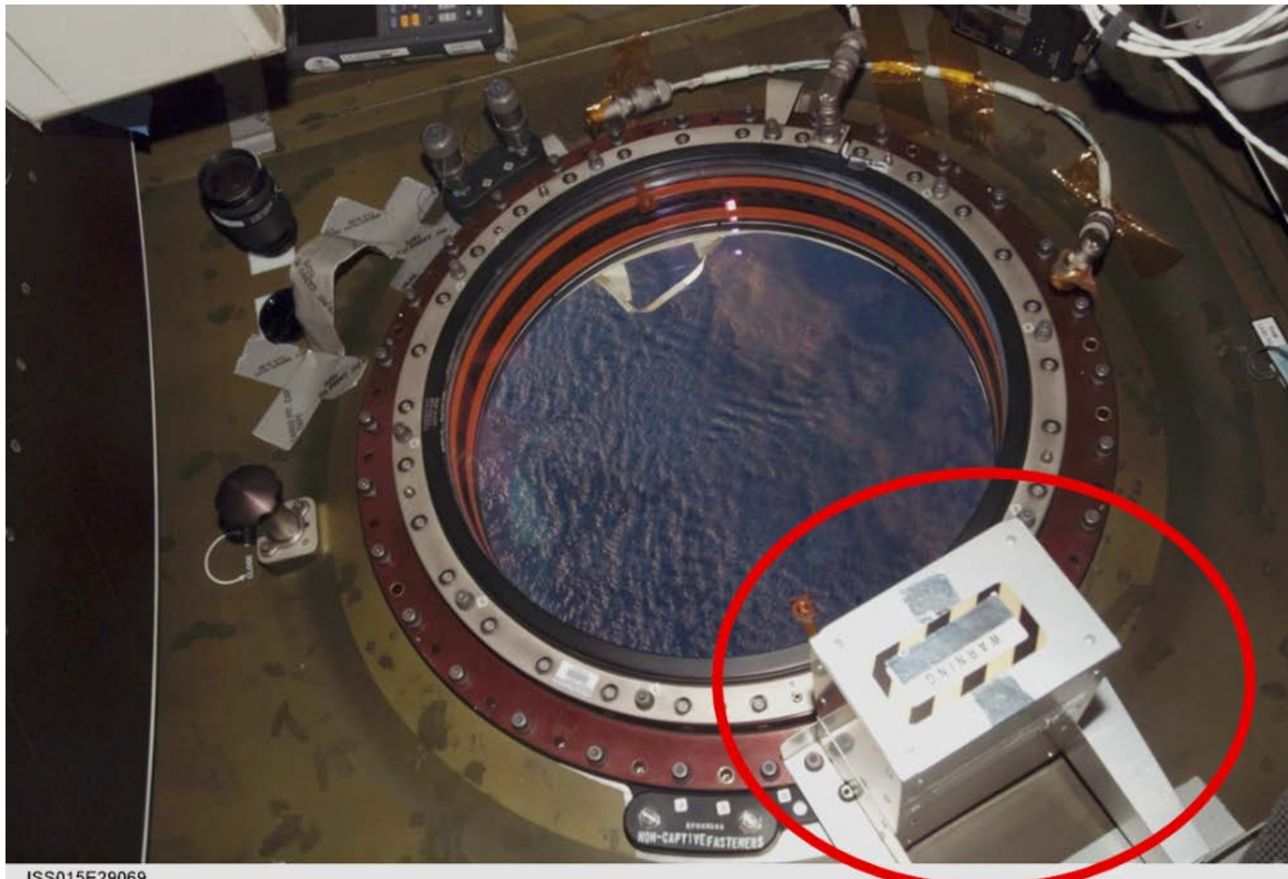
Think about that in the design phase so <u>this</u> doesn't have to become ...

A Quick Example: Lab Window Vacuum Line

… this



NASA Systems Engineering encompasses HSI

- Systems Engineering is a methodical, disciplined approach performed by multi-disciplinary teams to ensure NASA products meet customer's needs while balancing competing discipline concerns.
- Together NPR 7120.5E and NPR 7123.1B comprise the primary guidance within the Agency for managing NASA programs and projects.
- To that end NPR 7123.1B and the NASA SE Handbook contain significant HSI language and references.

Ref:
NPR 7120.5E, NASA Space Flight Program and Project Management Requirements
NASA/SP-2014-3705, NASA Space Flight Program and Project Management Handbook also called "PM Handbook"

NPR 7123.1B, System Engineering Processes and Requirements
NASA/SP-2016-6105, NASA Systems Engineering Handbook (links on next slide)

NASA SE Handbook and HSI Practitioner's Guide

- The NASA SE Handbook is available as two products (new to 2016)
  - NASA Expanded Guidance on Systems Engineering (NEN; electronic),
  - NASA Systems Engineering Handbook ('core' document; paper and electronic), NASA/SP-2016-6105 (coming in fall of 2016)
- NASA/SP-2015-3709, Humans Systems Integration (HSI) Practitioner's Guide, which supports performing HSI consistent with the NASA SE model
  - Handbook style document covering HSI best practices and practical information

Tip:

HSI PG
p. 1-2

Throughout this presentation, this icon provides the specific page number reference to HSI PG content

Ref:
Expanded Guidance for NASA SE - Vol 1 (NEN)
Expanded Guidance for NASA SE - Vol. 2 (NEN)
NASA/SP-2015-3709, HSI Practitioner's Guide (NTRS)

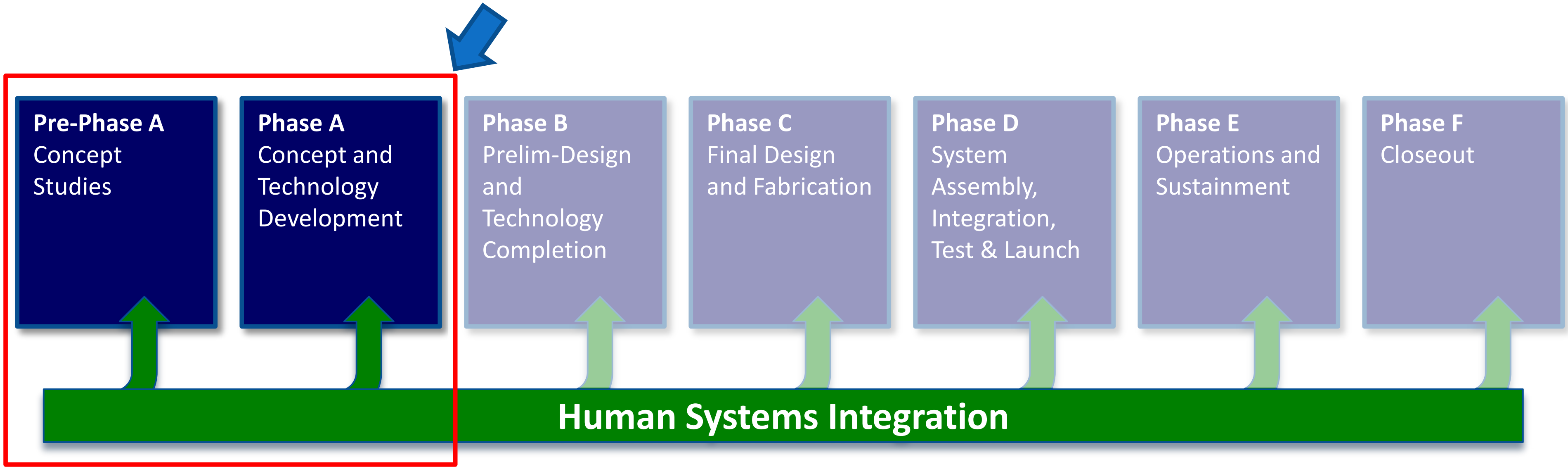
Why do HSI?

- HSI repeatedly validates the original intent of the system from a human perspective, making sure that the true purpose of the system isn't lost in the details
- HSI considers the points where humans and systems interact, and brings together users, experts, designers, and engineers to make sure system demands are within the capabilities of its users
- Continuous improvement: HSI systematically infuses information from past designs, operational use, and user feedback into systems development.
- HSI aims to contain lifecycle costs by bringing operations era experience to design and development with the intent of reducing manpower, skill demands, and training
- HSI is critical for mitigating risks in human/systems design and integration for NASA planetary mission success

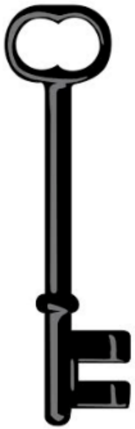
Keys to a Successful HSI Practice (Summary)

HSI PG p. 1-7

1. The human component of a system is as important as other components
2. Considerations should include <u>all</u> humans interacting with the system
3. Integration and Collaboration between stakeholders is required
4. Engage early in the Systems Engineering Life Cycle



Keys to a Successful HSI Practice



- ***Key 1:*** The program must acknowledge that the human is as important as other components of the system. *To do this properly requires equal emphasis **and** resources to support Human Systems Integration.*
    - Systems are composed of hardware, software, procedures, and the human, all of which operate within an environment
    - Sometimes engineers and developers inadvertently overlook human abilities and limitations as part of the system design process.
    - This leads to poor task allocation within the system, resulting in *technology driven* solutions, instead of *task driven* solutions, which can put the deployment goals at risk
    - It is critical that the human element be considered in system development. The earlier human concerns are incorporated, the more cost-effective the result

Participant Exchange:

- Why do you think developers sometimes fail to consider human concerns and limitations in design?

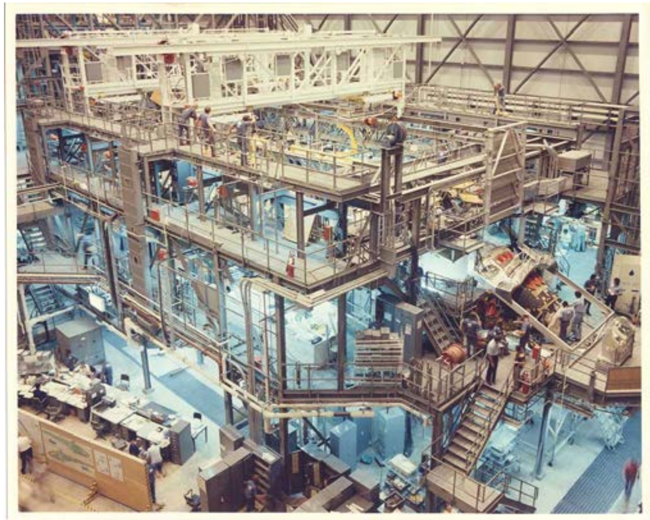
Participant Exchange

- Why do you think developers sometimes fail to consider human concerns and limitations in design?
  - Institutional "walls" between organizations
  - Lack of Training
  - Lack of full funding
  - Schedule Pressure
  - Inappropriate focus on solving technology problems rather than the mission or science objectives
  - "Designers just want to design"

Example: The Shuttle Concept vs. Reality

HSI PG
p. C-11

Concept
- "Jet aircraft" style hanger
- 5 weeks turnaround time
- 40 flights per year for fleet of 3 vehicles



Reality
- Elaborate scaffolding
- Large number of service workers required
- ~4 flights per year, average

Classic Problems
- Insufficient definition of Ops requirements
- Focus on Performance
- Developers not responsible for Operational Costs
- Very few incentives for addressing turn-around time or maintainability

Source: Bo Bejmuk, Space Shuttle Integration (Lessons Learned Presentation)
See HSIPG Appendix C section 2 for more details

Keys to a Successful HSI Practice

HSI PG
p. 1-10

- ***Key 2***: Considerations should include all personnel that interface with a system (not just crew).
  - The considerations should include any and all phases of the system life cycle
  - And applies to all expected environments
  - So just where do humans and systems interact? Who does HSI consider? A variety of personnel including:
    - The end users (pilots, crewmembers)
    - Ground controllers
    - Monitoring personnel
    - Trainers
    - Integration and Test personnel
    - Manufacturers
    - Maintainers
    - Logistics personnel

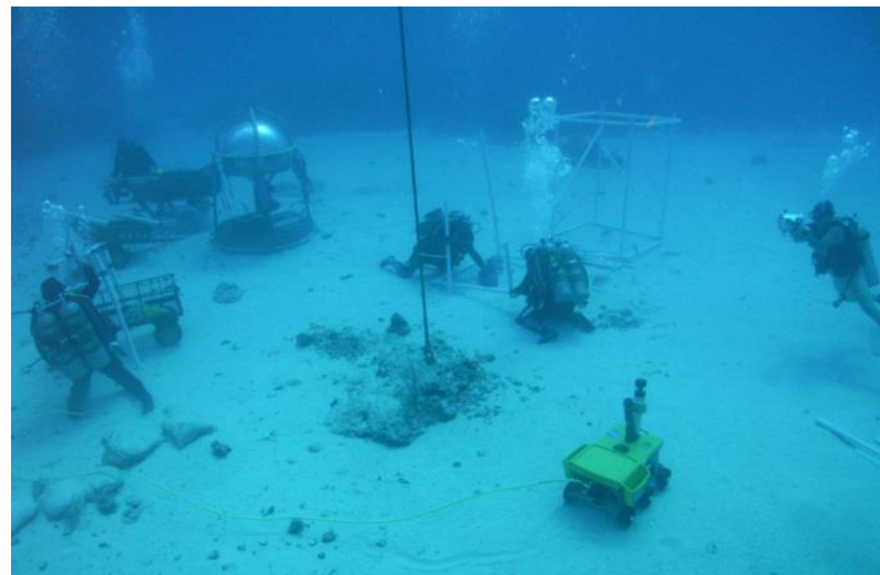
Example: Assessing Cognitive Performance in an Aviation Environment

Keys to a Successful HSI Practice

HSI PG
p. 1-10

- ***Key 2***: Considerations should include all personnel that interface with a system (not just crew).
  - The considerations should include any and all phases of the system life cycle
  - And applies to <u>all</u> expected environments

Emergency Egress

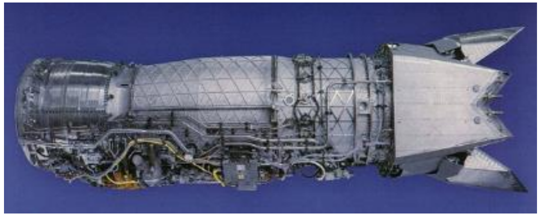


Aquanauts testing surface operations

Example: F-22 Raptor engine development

HSI PG
p. C-13

- Contracts were issued to 2 vendors to develop engines
  – Power for the F-22 Raptor Advanced Tactical Fighter (ATF)
  – Funded through to building functioning prototypes



F-119 Engine

- The Army, Navy, & Air Force signed a joint agreement to emphasize reliability & maintainability in this Joint Advanced Fighter Engine (JAFE) Program
  – This was in response to 50% (and growing) of USAF budget devoted to logistics costs

- The Air Force outlined a Reliability, Maintainability & Sustainability (RM&S) program for the JAFE to reduce life-cycle costs
  – By "reducing the parts count, eliminating maintenance nuisances such as…special-use tools, using common fasteners, improving durability, improving diagnostics, etc."

Example: F-22 Raptor engine development

HSI PG
p. C-13

- In response to DoD's clear RM&S goals, <u>one</u> of the contractors centered their competitive strategy on RM&S superiority
  - The strong contractor leadership set evaluation criteria in safety, supportability, reliability, maintainability, operability, stability, manpower, personnel, and training
  - Personnel with expertise in all DoD HSI domains (except Habitability) were engaged
  - Maintainers were brought in to participate in the design process
  - The contractor engaged and participated in Air Force maintainer forums to understand current facilities, tools, logistics, training, and procedures challenges
  - Several full-scale mockups were built allowing engineers to test the maintenance goals

F-119 Engine

Example: F-22 Raptor engine development

HSI PG
p. C-13

- Lesson Learned resulted in
  - An engine fully serviceable using only five different hand tools
  - Any line-replaceable unit (LRU) serviceable without removing any other LRU
  - Each LRU is removable in 20 minutes or less using only one tool
  - Service is possible while wearing hazmat gear
  - Service can be performed by 5^{th} to 95^{th} percentile maintainers
  - Built-in diagnostics eliminate the need for special support systems
  - Interchangeable components, computer based training, corrosion resistance, etc.
  - **Demonstrated reduction of ops level maintenance items by 75% and tools by 60%**

F-119 Engine

Example: F-22 Raptor engine development

HSI PG
p. C-13

Cited as an HSI Best Practice: F-22 Raptor engine development

<u>The Result</u>:

- **Despite the other engine delivering superior in-flight performance, the Air Force chose the contractor who had demonstrated superior RM&S performance**
  - Production contract worth over $1B was awarded

F-22 in afterburner

<u>Lessons</u>:

- **DoD leadership set clear HSI performance goals**
  - Shaped the outcome
- **Contractor leadership emphasized meeting HSI goals**
  - Established processes that engaged the user population throughout design
  - Set team goals and invested accordingly

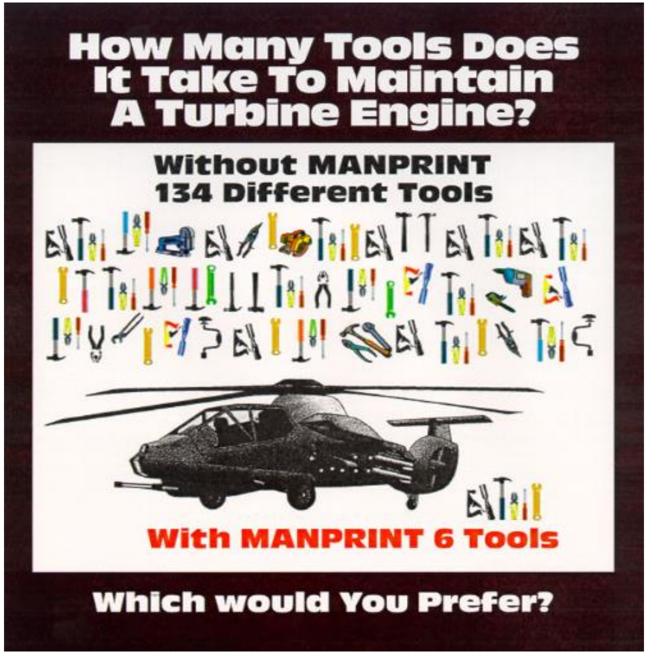
For further study: http://seari.mit.edu/documents/preprints/LIU_HSIS09.pdf
http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA518530

Also in appendix C, section 3 of NASA/SP-2015-3709, Human Systems Integration (HSI) Practitioner's Guide

Another DoD HSI Success Story

Comanche Tool Kit

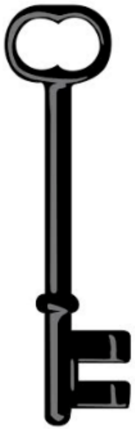
- The tool box for the T-53 series helicopter turbine engine (Huey & Iroquois) had 134 different tools.
- Because of MANPRINT and its inclusion of HSI in the design process, the tool KIT for the T-800 for the Comanche has **six** tools instead of 134
  - And the tools are inexpensive & commercially available
- **Result:**
  - Fewer tools
  - Less burden on the supply system
  - Less training and inventory time
  - Increased combat readiness



MANPRINT is the U.S. Army's Human Systems Integration Directorate

Keys to a Successful HSI Practice

HSI PG
p. 2-3



- ***Key 3***: HSI depends upon integration and collaboration of the Human-Centered Domains and stakeholders within the systems engineering lifecycle to speak with one voice
  - Often these domains exist as independent disciplines due to the location of expertise within the structure of NASA
  - Therefore, one domain may not be aware of what the other is doing
  - Implementation of HSI helps to bring all domains together, leveraging and applying their interdependencies in design
  - To do this, HSI is integrated into existing systems engineering and management processes
  - In this way domain interests are integrated to perform effective HSI through trade-offs and collaboration. This provides a common basis upon which to make informed decisions.

Participant Exchange:

- What are some of the potential barriers to integrating across disciplines?

Participant Exchange

- What are some of the potential barriers to integrating across disciplines?
  - Organizational boundaries
  - Lack of familiarity with other disciplines
  - A view that someone else will take care of it
  - A view that my Human Factors engineer will handle HSI

NASA Example: Collaboration with End-User = Success!

< "Before"

- Kits inside of Kits (design status quo)
- Highly organized but inflexible
- Harder to manifest and update for items with various expiration dates

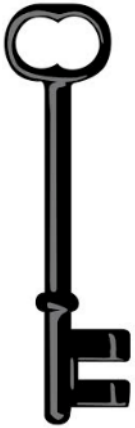
"After" crew comments >

- One big, open kit!
- Kept functionality
- Increased flexibility
- Improved resupply
- Looks less organized but is demonstrably effective
- Robust through "resupply failures"

A "counter-intuitive" design solution may have the lowest sustaining cost.

Keys to a Successful HSI Practice

HSI PG
p. 1-8



- ***Key 4***: HSI must be considered early and thoroughly in the conceptual design and requirements development phases of system design and acquisition (core SE practices)
  - To be cost effective, HSI must be included in the acquisition, systems engineering and program management cycles at their inception
  - Program managers and systems engineering must take ownership of HSI and be held accountable for the outcome
  - Start with a clear understanding of:
    - What the system (man + hardware + software) is supposed to do
    - Concepts of operations, which are continually revisited
    - Early functional allocation of roles within the greater system (what the human, hardware, and software are doing), for both nominal and off nominal scenarios
  - The approaches and strategies are captured in the HSI Plan *(see section III)*

The Goal of HSI is to Optimize Total System Performance while reducing Cost & Schedule

Why apply HSI early? Enhance Human System Design

Function Allocation Process

(HSI activities)

- Define System Goals → Identify Human Functions
- Create Requirements → Detail Human Performance
- Define Interfaces → Define User Interfaces
- Group by Functions → Assess Redundancy
- Trade Study > Architecture → Assess Automation

Pre-Phase A
Concept Studies

Phase A
Concept and Technology Development

Phase B
Prelim-Design and Technology Completion

Phase C
Final Design and Fabrication

Phase D
System Assembly, Integration, Test & Launch

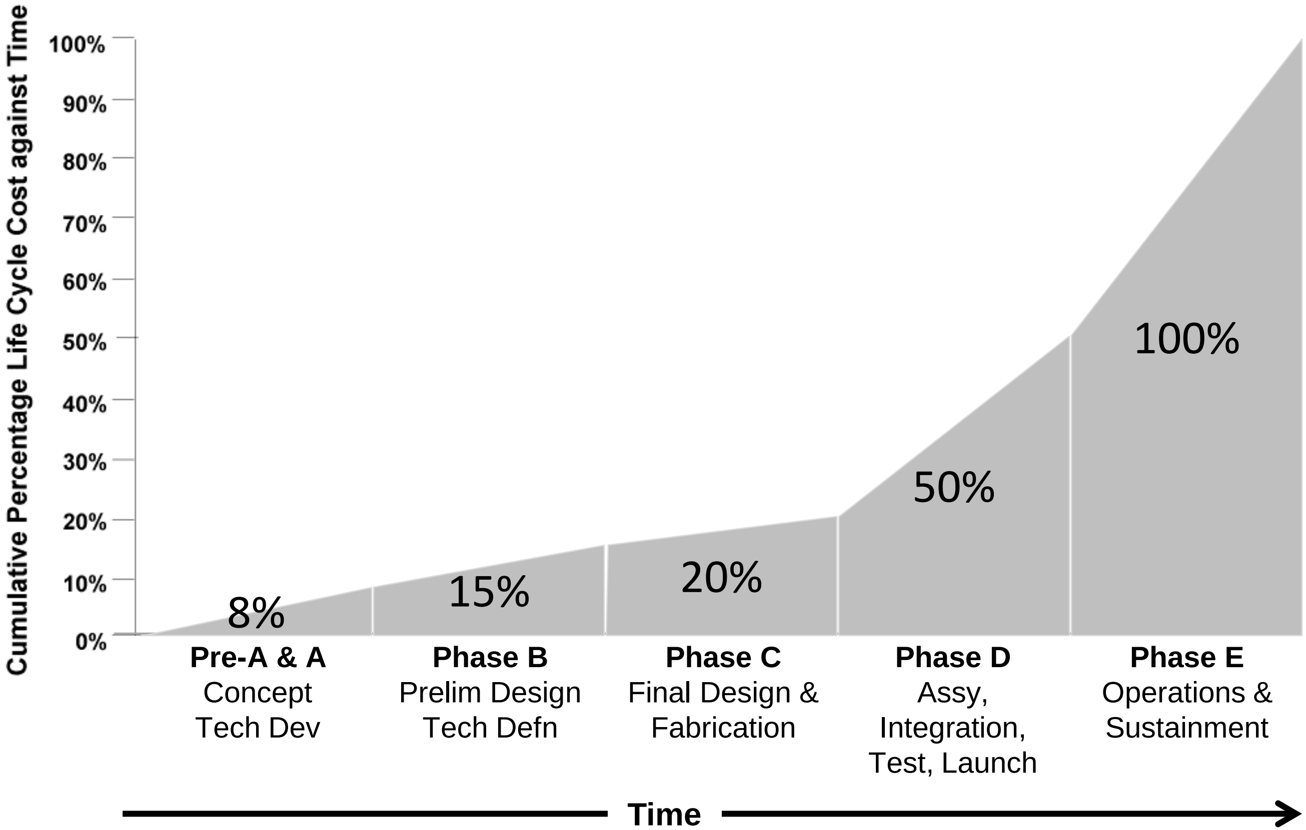
Phase E
Operations and Sustainment

Phase F
Closeout

Human Systems Integration

Why apply HSI early? Reduce Cost and Schedule

HSI PG
p. 1-9

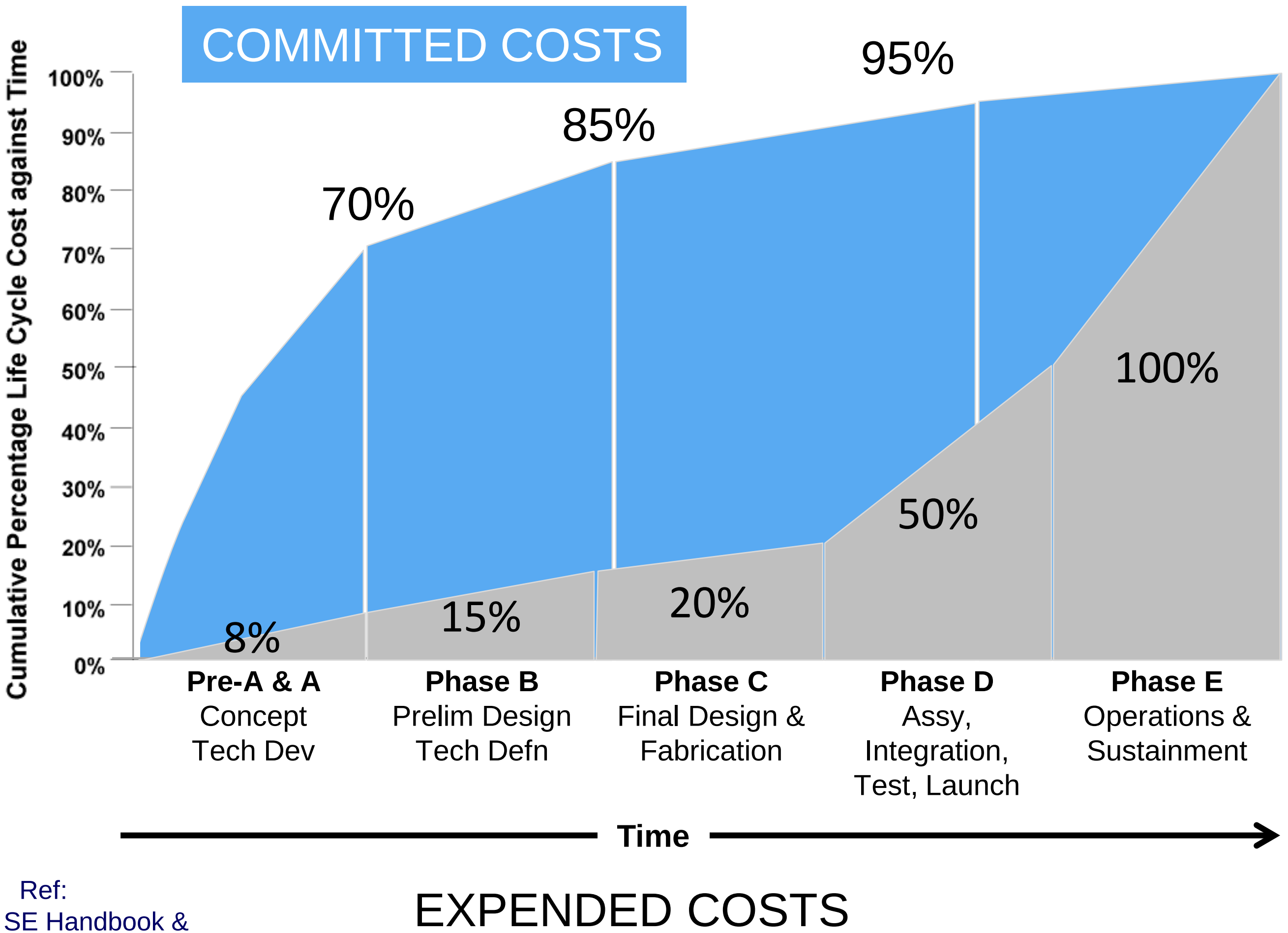


EXPENDED COSTS

Ref:
INCOSE SE Handbook &
Defense Acquisition University, 1993

Why apply HSI early? Reduce Cost and Schedule

HSI PG
p. 1-9



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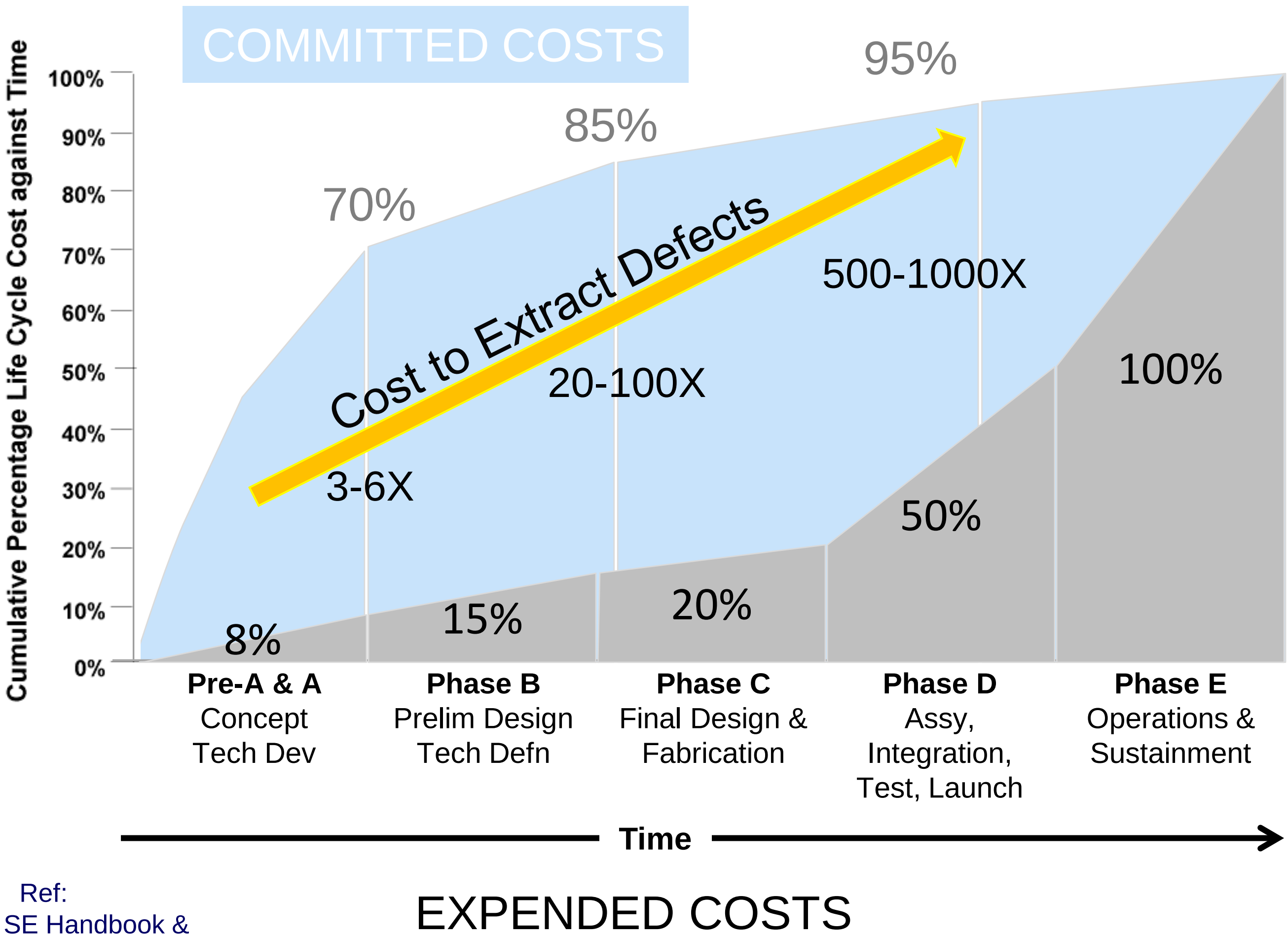
Why apply HSI early? Reduce Cost and Schedule

HSI PG
p. 1-9



Ref:
INCOSE SE Handbook &
Defense Acquisition University, 1993

Why early? Reduce risk

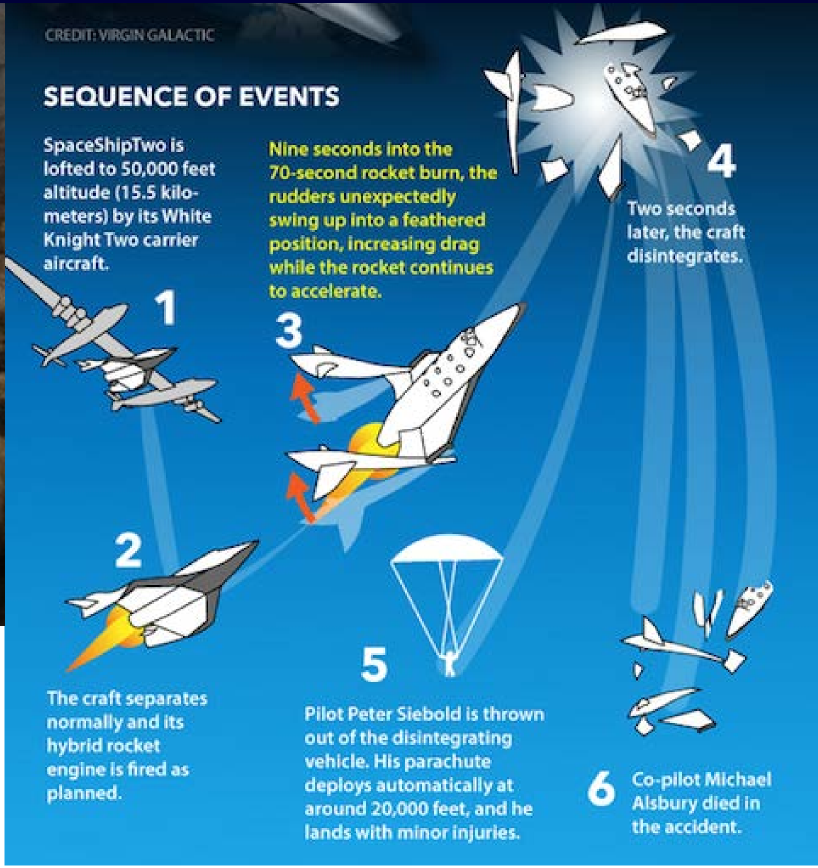
Genesis probe crash landing

Accelerometer for chute activation was installed upside down & per print

Accelerometer previously used successfully in another vehicle

Not retested for Genesis

Why early? Reduce risk



Virgin Galactic SpaceShip Two Failure

Root cause: Co-pilot error "premature repositioning" of the spacecraft's tail wings

No safeguards for human error

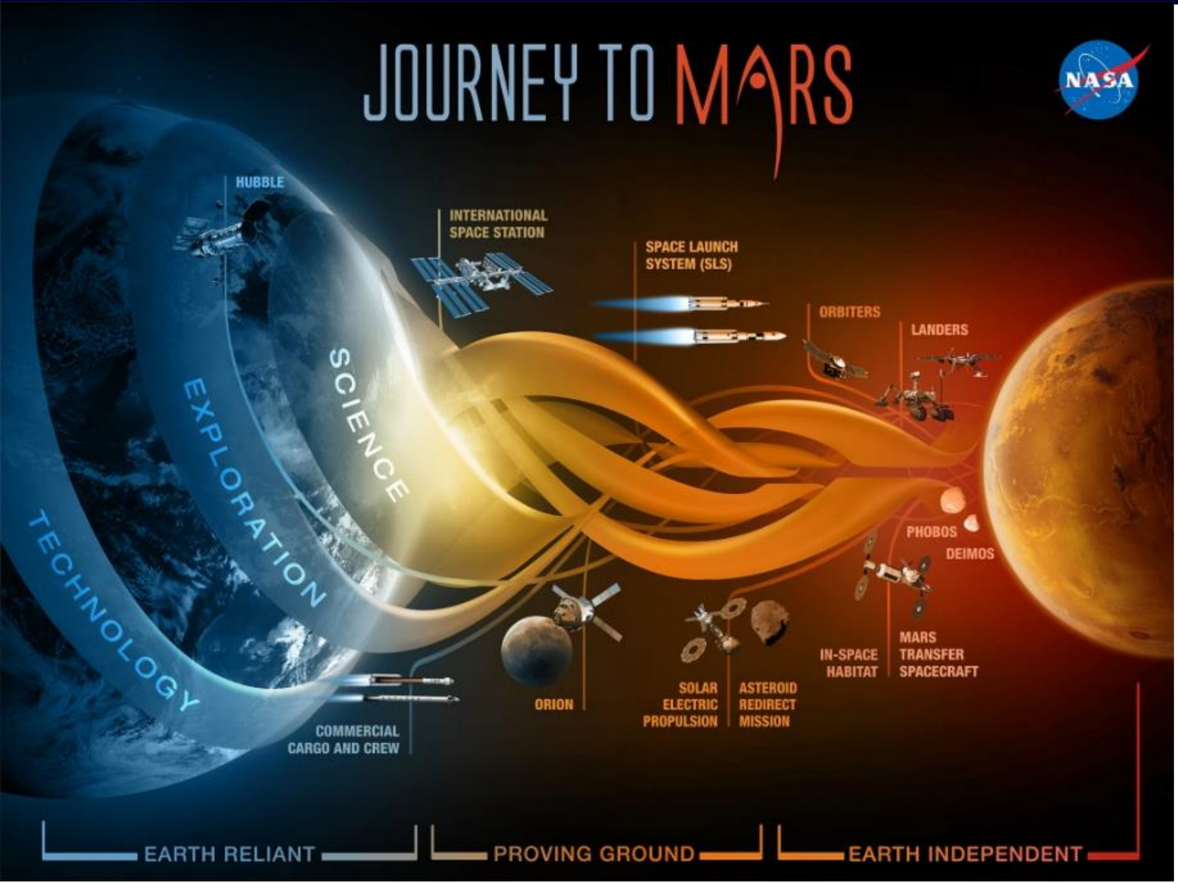
Why early? Optimize Total Systems Performance

- How do we integrate human performance considerations into the system?
- How do we ensure operators do not make errors at critical times?
- How do we ensure operators are not cognitively overloaded?
- How many maintainers with the right skills are needed?
- How can we design the system to prevent extraordinary amounts of training?
- How can we prevent the ops team from ‘fixing’ design flaws?
- **The solution is to conduct HSI throughout the SE lifecycle**
- From this, requirements for human performance are developed, and the total system performance can be evaluated for operability, sustainability, maintainability, safety, affordability, etc.

To go beyond earth orbit we must adopt HSI principles and address topics such as automation, autonomy, commonality, habitat sustainment, physiological and psychological concerns, etc.

Extra reading: Handbook of Human Systems Integration, Harold R. Booher © 2003 Wiley and Sons, Inc.

Mars is Hard



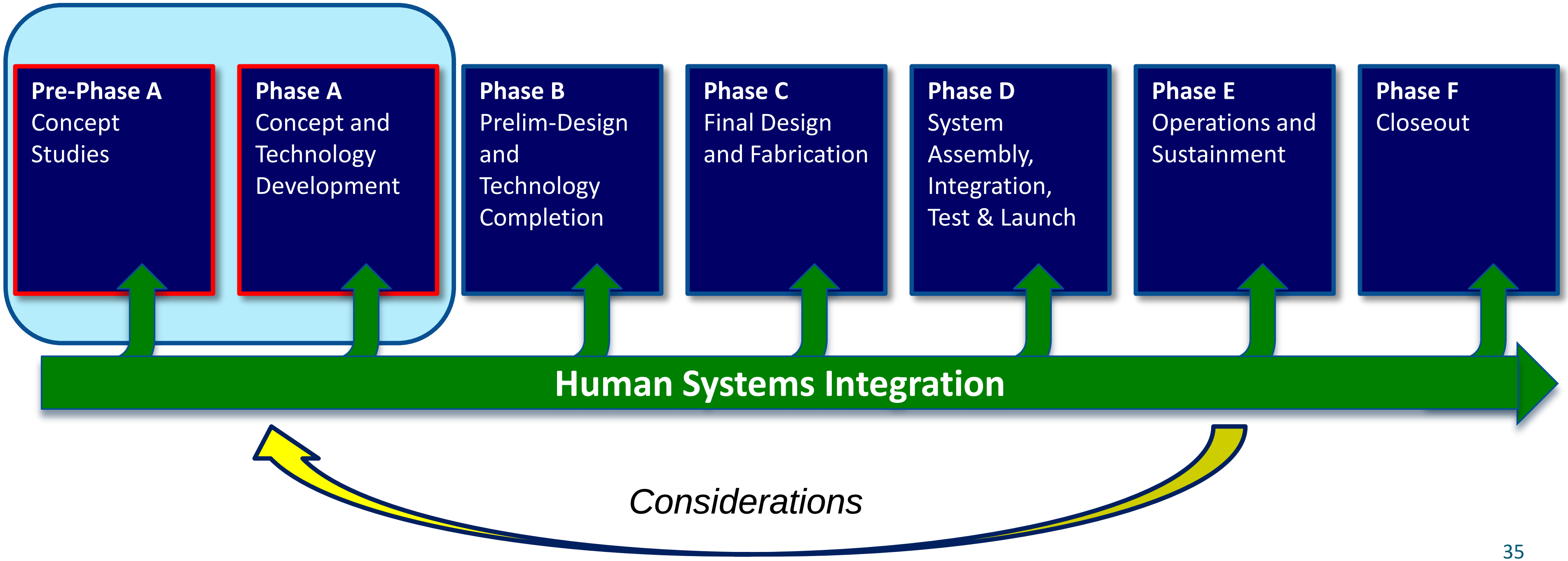
Besides technology advances as shown in the graphic, others are needed as well:

- Comm. Access
- Comm. Rate
- Healthcare autonomy
- Human Spaceflight Risk countermeasures
- Vehicle automation
- Vehicle autonomy
- In-flight and remote maintenance

"I would like to die on Mars. Just not on impact."
– Elon Musk

Brainstorming: Early Considerations?

What operational phase considerations should be addressed early in the life cycle for a human space flight project?



Participant Exchange

- What operational phase considerations should be addressed early in the life cycle for a human space flight project?
  - Mission objectives and crew "staffing"
  - Concept of Operations
  - Constraints
  - Cost to verify / make safe
  - Technology Readiness Levels
  - "All of them"

Training should not be the countermeasure to bad design.

The Promise of HSI

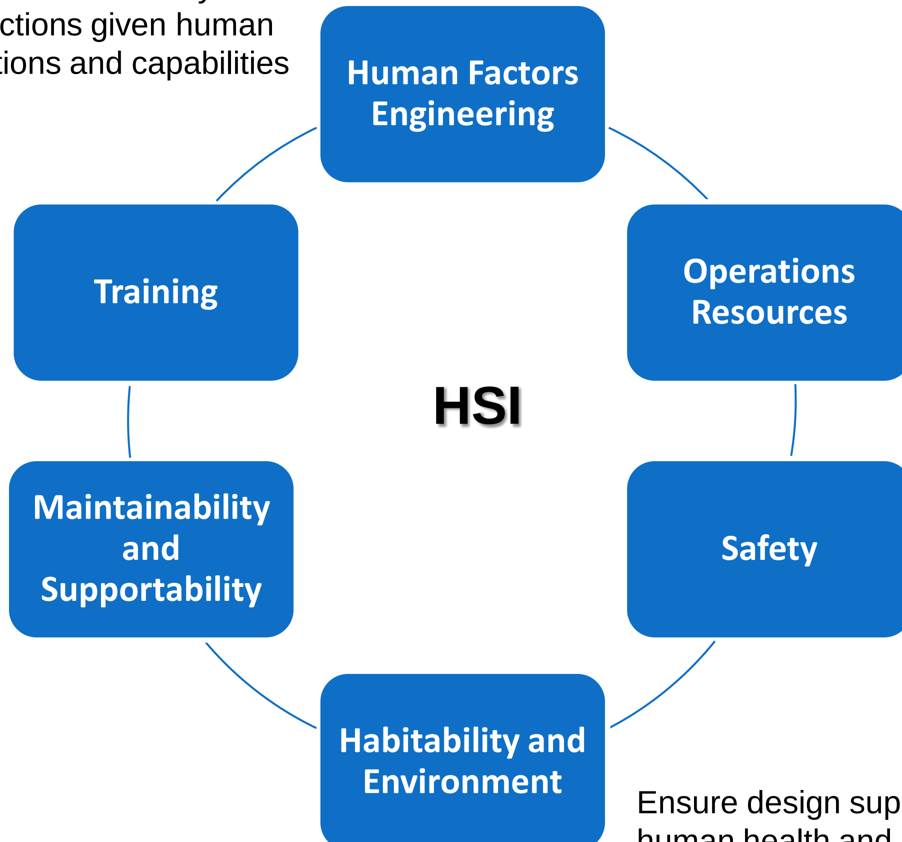
- System Optimizations due to:
  - Reduced manpower numbers
  - Simplified requirement for personnel skills
  - Reduced training needs
  - Simplified maintenance and logistics
  - Mishap avoidance
  - Avoidance of system rework costs

- Designs focused on the needs of operators, maintainers, and other support personnel
- Demonstrates “return on investment” of HSI in human spaceflight through engagement of all domains and organizations
  - Stakeholders and domains are engaged early and often in the lifecycle
- Promotes total system performance (increased effectiveness and efficiency)

Next, we will look at the domains and roles for conducting HSI activities

NASA HSI Domains Overview

HSI PG
p. 1-11



Design for human-system interactions given human limitations and capabilities

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

Minimize risks to personnel and design for mission success

Ensure design supports crew 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

HSI Roles

- There are several key roles in the implementation of HSI
  - HSI Practitioners
  - Domain experts
  - Process and Organizational Stakeholders

- HSI Practitioners
  - HSI requires being equipped with knowledge and tools on how to integrate human performance and capacities into research, design, development, and system implementation, plus understand the NASA Systems Engineering Process
  - The demand for practitioners will naturally grow as a result of improved HSI requirements and implementation
  - There is a growing need for new and additional HSI education and training programs to:
    - Serve the needs of existing practitioners
    - Support new personnel who wish to become HSI practitioners
    - Increase and help to facilitate HSI awareness and value-add within the NASA community (including program/project management)
    - Develop tools to facilitate HSI practice

HSI Roles *(continued)*

- Domain Experts
  - Domain experts are subject matter expects (SMEs) for specific technical domains
  - To establish effective HSI in a program it is necessary to identify and include HSI competencies and formalized collaboration amongst the domain experts
    - This may require gap analysis to identify HSI skill sets needed to meet current and anticipated HSI workload
  - They should have academic backgrounds and experience to accomplish the desired tasks. These backgrounds and experience will vary from project to project

- Process and Organizational Stakeholders
  - Groups that are directly impacted by the outcomes of the HSI work (e.g., program managers, systems engineers, subsystem management, crew, etc.)
  - This is a huge category, and underscores how there are many organizations and types of personnel who need to engage in HSI
  - Program/project manager ‘buy-in’ is a must to make HSI successful!

Section I: Summary

- HSI is mandated by NPR 7123.1B and is tied to NASA systems engineering
- HSI is process-focused, implemented by a collaborating team
- HSI benefits performance, cost, and schedule by influencing early decisions
- HSI utilizes a diverse group of experts and practitioners
- HSI practitioners work to keep the focus on the operational goals throughout the development process

Next up: Section II – HSI in the SE Life Cycle

Section II

HSI in the Systems Engineering & Integration Lifecycle

- **Fundamentals**: Systems Engineering (SE) Life Cycle
- **Process**: Systems Engineering Engine (SEE)
- **Integration**: HSI in the SE Life Cycle & SEE

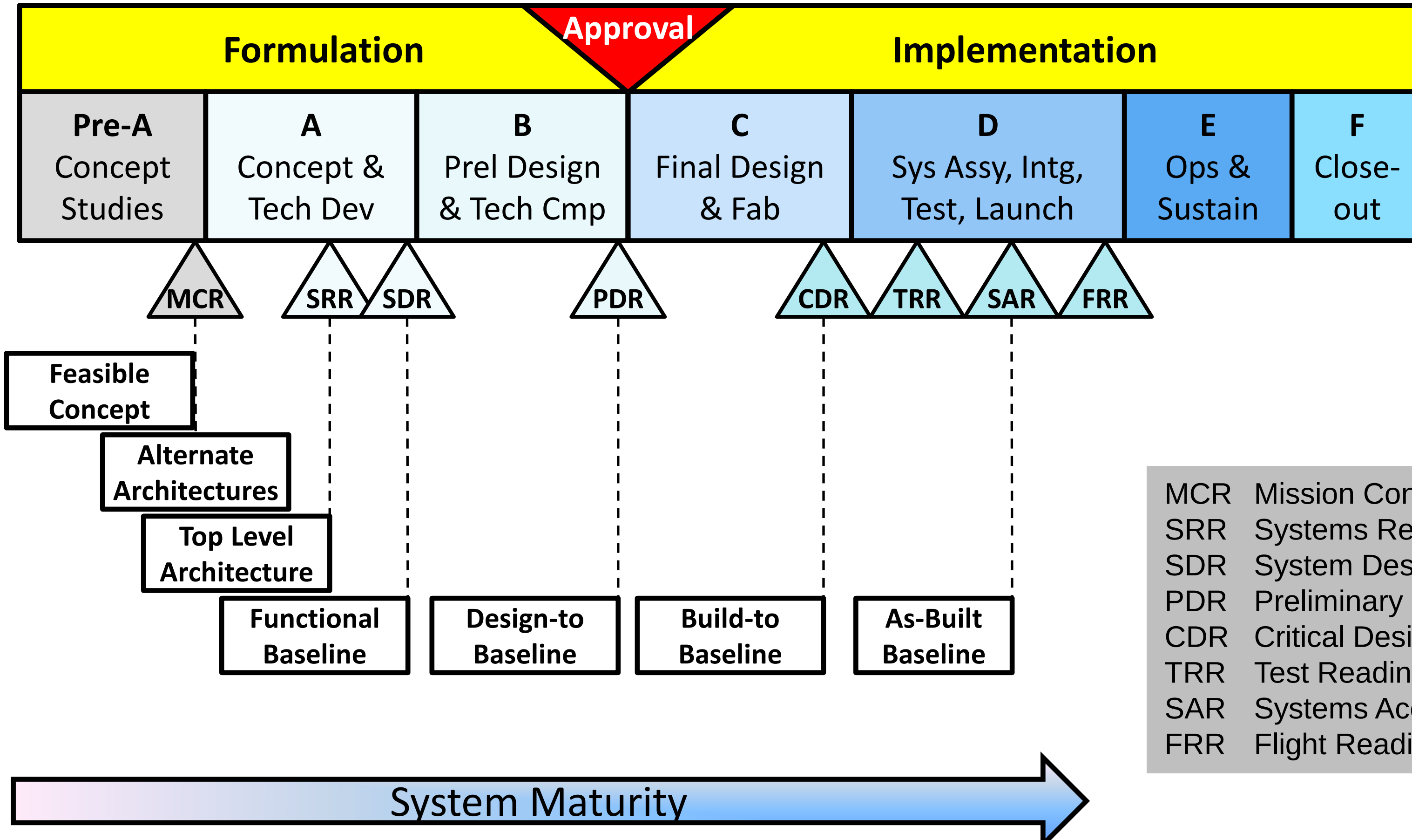
NASA Systems Engineering

- Within NASA, NPR 7123.1B defines the Systems Engineering (SE) processes and requirements
- The systems engineer is skilled in the art and science of balancing organizational and technical interactions in complex systems
- Systems engineering is about tradeoffs and compromises, about generalists rather than specialists
- Systems engineering is about looking at the “big picture” and not only ensuring that the project manager gets the design right (meeting requirements) but that they get the right design (one that meets the original deployment goals)
- The proper planning and execution of HSI in a program/project resides with the skilled HSI practitioner working under and with the systems engineering team

NASA Uses 2 models: Life Cycle and the SE Engine

NASA Systems Engineering Life Cycle

HSI PG
p. 1-8

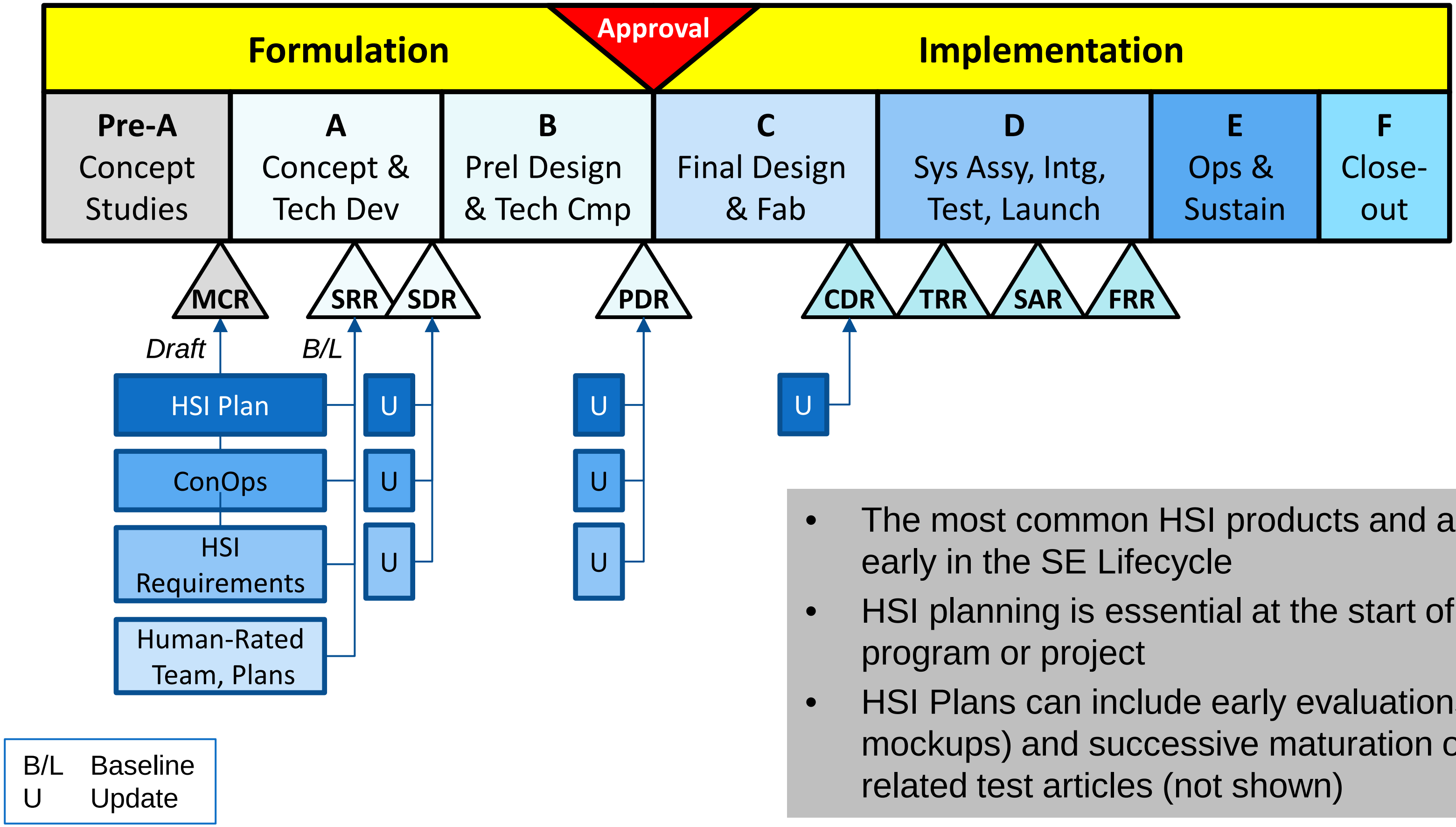


MCR	Mission Concept Review
SRR	Systems Requirements Review
SDR	System Design Review
PDR	Preliminary Design Review
CDR	Critical Design Review
TRR	Test Readiness Review
SAR	Systems Acceptance Review
FRR	Flight Readiness Review

Simplified; typical for most projects per NPR 7120.5

Common HSI Products in the SE Life Cycle (Simplified)

HSI PG
p. 3-4



- The most common HSI products and activities occur early in the SE Lifecycle
- HSI planning is essential at the start of any new program or project
- HSI Plans can include early evaluations (human mockups) and successive maturation of human-related test articles (not shown)

HSI Plan, ConOps, HSI requirements per NPR 7120.5E; Human-Rating Requirements per NPR 8705.2B

HSI Activities By Life Cycle Phase *(Summary)*

HSI PG Section 3

Life Cycle Phase	Phase Title	KDP Milestone	Activities to support KDP
Pre-Phase A	Concept Studies	MCR	• Identify the roles of humans in performing mission objectives (i.e., flight and ground crew) • Perform tradeoffs and analyses of alternatives (AoA) • Develop scenarios and concept of operations (ConOps)
Phase A	Concept & Technology Development	SRR MDR/ SDR	• HSI Team stood up by SRR* • HRCP Input: Crew Workload Evaluation Plan* • Function allocation, crew task lists (ConOps) • Iterative conceptual design and prototyping • Start HSI Planning
Phase B	Preliminary Design & Technology Completion	PDR	• HRCP Report: HITL usability eval plan, results, and influence on system design* • Iterative design and prototyping, task analysis, validation plans

* Ref: NPR 8705.2B   Key Decision Point (KDP) Ref: 7120.5E   For a comprehensive list see, the HSIPG

HSI Activities By Life Cycle Phase *(Summary)*

HSI PG Section 3

Life Cycle Phase	Phase Title	KDP Milestone	Activities to support KDP
Phase C	Final Design & Fabrication	CDR	• HRCP Report: HITL usability eval plan, results and influence on system design (update for CDR)* • Complete validation planning
Phase D	System Assembly, Integ. & Test, Launch & Checkout	TRR SAR ORR/FRR	• HRCP Report: Human system performance tests results* • Testing to validate human-centered design assumptions
Phase E	Operations & Sustainment	PLAR CERR PFAR	• Monitoring of human-centered design performance
Phase F	Closeout	DR/DRR	• Lessons Learned

* Ref: NPR 8705.2B

Key Decision Point (KDP) Ref: 7120.5E

For a comprehensive list see, the HSIPG

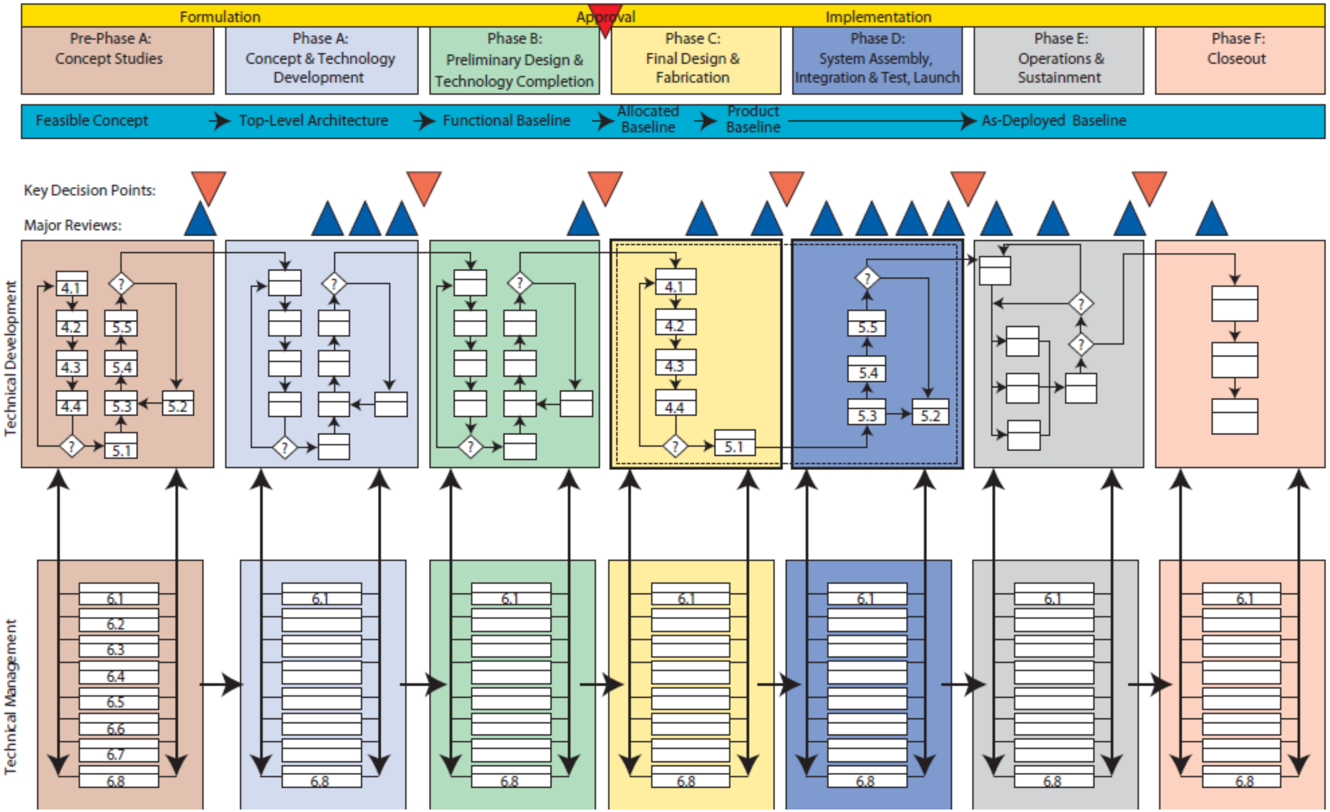
But wait, there's more... the 17 SEE Processes

- For each and every Phase, NPR 7123.1B describes what to do in term of activities: 17 Systems Engineering Engine (SEE) Processes

NASA 7 Life Cycle Phases

SEE Technical Processes Executed In Each Phase

SEE Cross-cutting Processes Executed In Each Phase



NASA Systems Engineering Engine (SEE): 17 Processes

Technical Management Processes

Technical Planning Process
10. Technical Planning

Technical Control Processes
11. Requirements Management
12. Interface Management
13. Technical Risk Management
14. Configuration Management
15. Technical Data Management

Technical Assessment Process
16. Technical Assessment

Technical Decision Analysis Process
17. Decision Analysis

Cross-Cutting

System Design Processes

Requirements Definition Processes
1. Stakeholder Expectation Definition
2. Technical Requirements Definition

Technical Solution Definition Processes
3. Logical Decomposition
4. Design Solution Definition

Product Realization Processes

Product Transition Process
9. Product Transition

Evaluation Process
8. Product Validation
7. Product Verification

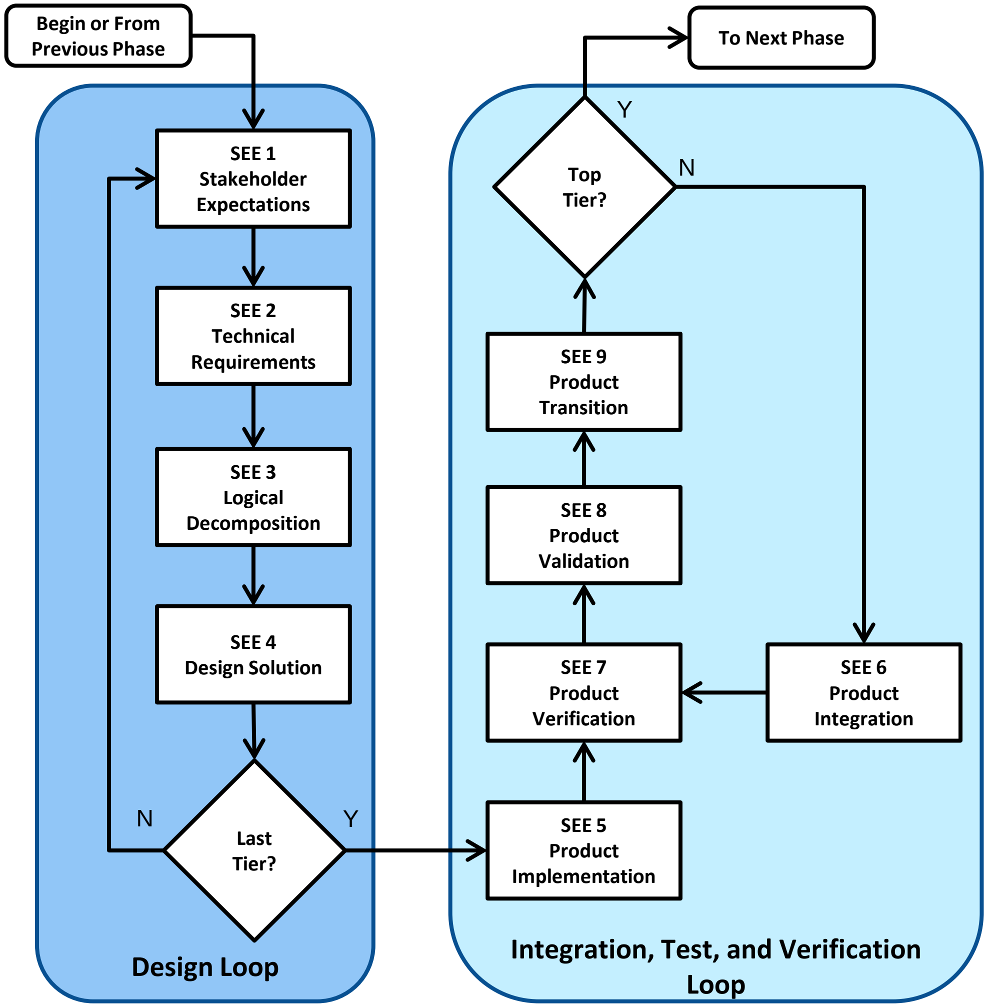
Design Realization Process
6. Product Integration
5. Product Implementation

NPR 7123.1B contains a flow chart and explanation <u>for each</u> process

NPR 7123.1B, Systems Engineering Engine

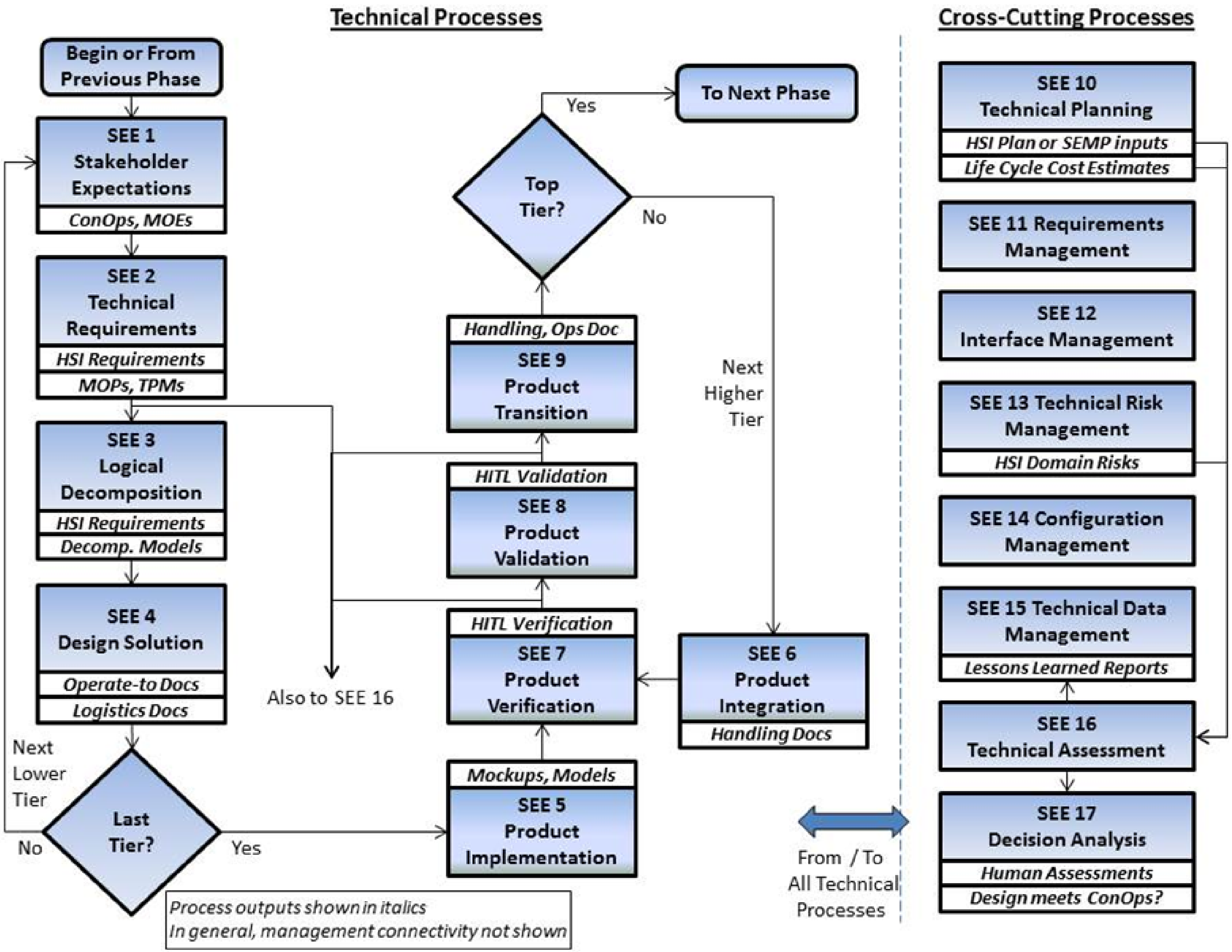
Technical Development Loop Mechanics

- This design loop repeats for each Life Cycle Phase
- The design loop repeats for each level of the architecture
- The I, T & V loop repeats for each level of the architecture
- Details for each process is provided in NPR 7123.1B and SEHB



SEE with HSI Inputs and Outputs (*Highly Summarized*)

HSI PG
p. 3-3



Products are matured by iteration at each level, and successively in the next Life Cycle Phase

HSI and Key Decision Points

HSI PG Section 3, by Phase

- The progress between lifecycle phases is marked by Key Decision Points (KDPs)
- At each KDP, management examines the maturity of the technical aspects of the project.
- For example, management examines whether resources (staffing and funding) are sufficient for the planned technical effort, whether the technical maturity has evolved, what the technical and non-technical internal issues and risks are, or whether the stakeholder expectations have changed.
- If the technical and management aspects of the project are satisfactory, including the implementation of corrective actions, then the project can be approved to proceed to the next phase.
- Per NPR 7123.1B, planning is conducted to define the HSI assessment functions at KDPs and other key points in the engineering lifecycle.
- What is necessary for HSI and KDPs?
    - Entry and exit criteria: **METRICS!**
    - They should be evaluated at every key decision point
- Measurable methodologies are needed for determining HSI success

HSI and Key Decision Points *(continued)*

- HSI entry and exit criteria need to be established for major milestone reviews and decision points, for example:
  - Key Decision Points A-F (the gates between each phase transition)
  - Milestones at select program reviews such as: SDR (System Definition Review), PDR (Preliminary Design Review), CDR (Critical Design Review), FRR (Flight Readiness Review)

- To accomplish HSI inclusion and assessment, HSI practitioners are established as core members of the Integrated Product Teams (IPTs), Working Groups, and Control Boards
  - Provides an opportunity to ensure critical HSI metrics are embedded within design reviews, tradeoff studies and assessments
  - Allows for on-going review and integration of HSI
  - NPR 8705.2B mandates the formation of an HSI Team

Examples of HSI Content – Milestones

HSI PG
p. 3-19
p. 3-20

Table 3.5-1 Goals and Success Mapping for HSI in Phase B

Milestone	HSI Goal	HSI Success Criteria
PDR	Refine requirements; form and validate derived Human requirements	The top-level human requirements, including mission success criteria, TPMs, and any sponsor-imposed constraints are agreed upon, finalized, stated clearly, and consistent with the preliminary design. The flow down of verifiable requirements is complete and proper.
	Update SEMP, HSI Plan, and other technical plans	Definition of the technical interfaces (both external entities and between internal elements) is consistent with the overall technical maturity and provides an acceptable level of risk.
	Refine, validate, and document technical requirements	The operational concept is technically sound, includes human systems, and includes the flow down of requirements for its execution. Technical trade studies are mostly complete in sufficient detail and the remaining trade studies are identified, plans exist for their closure, and potential impacts are understood.
	Refine interfaces and evaluate compatibility	Appropriate modeling and analytical results are available and have been considered in the design.

Table 3.5-2 Process-Product Mapping for HSI in Phase B

SEE Process	Process Title	Key HSI Activities	Major HSI Products per Milestone
2	Technical Requirements	Define TPMs for human performance	**PDR**: HSI MOPs refined, TPMs defined and tracked
3	Logical Decomposition	Refine requirements; form and validate derived Human requirements	**PDR**: Requirements iterated and refined for preliminary design; ConOps further developed and matured
4	Design Solution	Prepare for detailed design, manufacturing, and testing	**PDR**: Support initial development of manufacturing, logistics, training, and testing plans
5	Product Implementation	Produce mockups, models, prototypes, and demonstrators	**PDR**: Support development of products used for human assessments
6	Product Integration	Ensure solution is compatible with integration philosophy	**PDR:** Plans/processes for integration of lower tier products
7	Product Verification	Prepare to conduct verification; conduct trial verification for high risk items	**PDR**: Models and prototypes are planned and developed; Crew Task Analyses conducted
8	Product Validation	Prepare to conduct validation; conduct trial verification for high risk items; evaluate design against ConOps	**PDR**: Models and prototypes are planned and developed
10	Technical Planning	HSI inputs to SEMP, HSI Plan, and other technical plans	**PDR**: HSI Plan iteration and update
13	Technical Risk Management	Conduct technical risk assessment; implement mitigation plans	**PDR**: HSI Plan, HSI Domain plans, and P/P risk management plans
17	Decision Analysis	Conduct decision analysis process for identified technical issues including HSI concerns	**PDR**: HSI process feedback iterations at each milestone

The HSI PG contains Milestone goals, activities, and products for each life cycle phase.

Example: Product Maturity Matrix

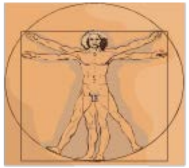
HSI PG
p. 3-4

Table 3.1-3 Product Maturity Matrix for Programs and Projects

Phase	Pre-A	A		B	C		D				E	F
Milestone Review / Product	MCR	SRR	SDR/ MDR	PDR	CDR/ PRR	SIR	TRR	SAR	ORR	FRR	PLAR/ CERR	DR/ DRR
Conceptualization and Architecture												
Concept Documents, ConOps	D	I	U	U								
Function allocation to Humans (Flight Architecture)	D	I	U	U								
Function allocation to Humans (Ground Architecture)	D	D	I	U								
HSI Decomposition Models for Requirements Development	D	U	U	U								
HSI Requirements (Project and System)	D	I	U	U								
HSI Requirements (Subsystem)	D	D	D	I								
HSI inputs to technology maturation	I	U	U	U	U							
Human mockups, models, prototypes	X	X	X	X	X	X						
Human Assessments, Human-systems interactions			X	X	X	X						
Validate design to ConOps			X	X	X	X		X		X	X	
Cross-cutting and Management												
HSI Planning for SEMP or HSI Plan	D	I	U	U	U	U						
HSI-applicable Trade Study reports	X	X	X	X	X	X						
Measures of Effectiveness (MOEs)	D	D	I	U	U	U						
Measures of Performance (MOPs)	D	D	I	U	U	U						
Technical Performance Measures (TPMs)	D	D	I	U	U	U						
Life Cycle Cost Estimates	D	D	I	U	U	U	U	U	U	U	U	U
HSI Domain Risks	I	U	U	U	U	U	U	U	U	U	U	U
Lessons Learned Reports	X		X	X		X				X	X	X
Production and Operations												
Operations Concept	D	D	D	I	U	U		U	U			
Human-in-the-Loop Testing				X	X	X	X	X				
Operate-to Documents			D	D	I	U	U	U	U			
Logistics Documents			D	D	I	U	U	U	U			
Handing and Ops Documents					D	I	U	U	U	U		
Monitoring of human performance								X	X	X	X	

Legend: D – Draft, I – Initial baseline, U – Update, X - Applicable

HSI "Document Tree"



NASA Experience

NPR 7123.1B

NASA Systems Engineering Processes and Requirements

April 18, 2013

National Aeronautics and Space Administration

Revision B issued 2013 incorporated HSI

SP-2014-3705

Program and Project Manager's Handbook

National Aeronautics and Space Administration

Major update
Drafted in 2014 with HSI content
"Body of Knowledge" Spring 2016
"Core" Fall 2016

SP-2015-3709

Human Systems Integration (HSI) Practitioner's Guide (HPG)

National Aeronautics and Space Administration

Baseline 2015

Ref:
Expanded Guidance for NASA SE - Vol 1 (NEN)
Expanded Guidance for NASA SE - Vol. 2 (NEN)
NASA/SP-2015-3709, HSI Practitioner's Guide (NTRS)

The HSI Practitioner's Guide Role at NASA

- NASA has implemented a new approach: Incorporate HSI into the existing SE processes and methodology for success within NASA
- The 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

Exercise:

- In what other ways can we foster or facilitate effective HSI?

Participant Exchange

- In what other ways can we foster or facilitate effective HSI?
  - Cross-training
  - Rotational Assignments
  - Collaborative Engineering
  - Lessons Learned
  - Community of Practice
  - Self-study

HSI Myths and Realities

- Designers intuitively understand the human needs of the system because, after all, they are human.
  - Assumptions about human capabilities, individual variation, and how to accommodate for these parameters are the start of many HSI failures
  - Designers who rely on their own internal human knowledge assume they know all that is needed about the people for whom their system is designed

Myth!

- Training is a cost effective way to work around design shortcomings
  - Incorrect! Proper designs reduce the needs for training. Using training as a stop-gap measure to solve design problems results in higher operational costs in the development of courses, workarounds, and instructors
  - This type of mentality is also a sign of willingness to accept unnecessary risk
  - *Design it right the first time! Design for Operations efficiency!*

Myth!

HSI Myths and Realities

Myth!

- Adding HSI to a program/project costs money we may not have
  - This is a common misconception, which ultimately results from a lack of total lifecycle cost ownership.
    - It is a focus on immediate cost versus lifecycle cost.
    - HSI inclusion during Development may add some initial expense.
  - However, proper application of HSI will result in meeting mission objectives and cost savings in the operational era
  - Early and continuous inclusion of HSI reduces total lifecycle cost, leading to significant reduction of operations costs.

Reality!

- HSI can reduce life cycle costs by using the existing systems engineering practices and “systems thinking” to create human-focused products.
  - Current processes are in place
  - HSI adds a more formalized organization (HSI Team) to keep the SE process focused on continually validating the design and keeping the end user in mind.

HSI Myths and Realities

- HSI is just a new name for Human Factors Engineering (HFE)
  - Not true!
    - HSI is focused on the technical development ***process*** and integration of multiple domains about broad issues with a collaborative approach.
      - Ex: Management, planning, assessment and decision-making.
    - HFE is focused on the technical aspects of ***design*** about specific issues. HFE is a discipline of HSI.
      - Ex. Task assessment, functional allocation, man-machine interface.
      - In some contexts, HFE is construed rather narrowly (fonts and colors, knobs and dials) and then equated to HSI (incorrectly)

Myth!

- I can rely on the crew to do on-board maintenance.
  - Not a safe assumption – beware of the boomerang effect.
  - If your device requires a lot of maintenance time, it is highly likely that you won't get it AND that you'll be asked to perform additional analysis to evaluate allowing your device to continue to operate without it.

Myth!

Section III

Implementing HSI in the NASA Environment: HSI Practitioner's Guide

HSI Practitioner's Guide Structure

Ch.	Short Title	Purpose	Location in this pitch
1	Introduction to HSI	"Why HSI" Background, History, Key Concepts, HSI Domains	Section I
2	Implementing HSI	"Who" Authority hierarchy, NASA HSI Documents, Collaboration	Section I
3	HSI in NASA SEE	"When" and "What" Phase-by-Phase HSI Overlay to NASA SEE, Product maturity by Phase	Section II
4	Planning and Execution	"How" Getting Organized, Tailoring for Program/Project Size, Planning for HSI, Key Skills for the HSI Practitioner	Section III
App A	HSI Plan Outline	Annotated HSI Plan outline	-
App B	HSI Planning Checklist	Sample of checklist to aid practitioner in assessing scope of HSI effort	Section III*
App C	HSI Implementation Experiences	HSI implementation examples with positive/negative lessons learned and HSI ideal state	-
App D	References	List of HSI information from NASA, Industry, DoD, and other sources	-

* See HSI PG for complete checklist

HSI Domains – More details

HSI PG
p. 1-11

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 by 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) to support robust integration of all humans interacting with a system throughout its life cycle. HFE solutions are guided by three principles: system demands shall be compatible with human capabilities and limitations; systems shall enable the utilization of human capabilities in non-routine and unpredicted situations; and systems shall tolerate and recover from human errors.	Task analysis, human performance measures (workload, usability, situation awareness), HFE Design (anthropometry and biomechanics, crew functions, habitat architecture), HITL Evaluation, Human Error Analysis, Human-system Interface, Systems Design, and HFE Analysis
Operations Resources	The considerations and resources required for operations planning and execution. This includes operability and human effectiveness for flight and ground crews 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 crew, human/machine resource allocation, Mission Operations, Resource modeling and complexity analysis, Flight Operations, procedure development, crew time, staffing/qualifications analysis

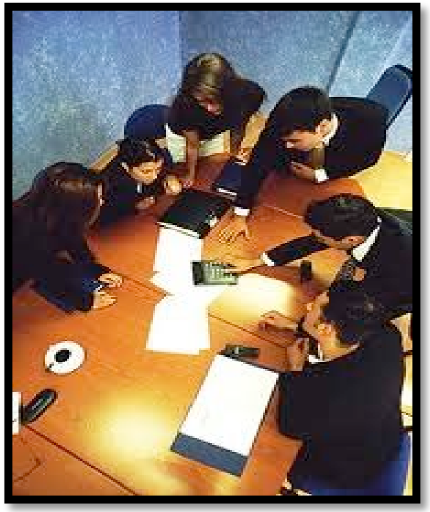
HSI Domains – More details

HSI PG p. 1-11

Domain	Definition	Examples of Expertise
Maintainability and Supportability	Design to simplify maintenance and optimize human resources, spares, consumables, and logistics, which are essential due to limited time, access, and distance for space missions.	In-flight Maintenance and Housekeeping, Ground Maintenance and Assembly, Sustainability and Logistics
Habitability and Environment	External and internal environment considerations for human habitat and exposure to natural environment including 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 Crew Health and Countermeasures, EVA Physiology, Medical Concerns, Lighting
Safety	Safety factors ensure the execution of mission activities with minimal risk to personnel. Mission success includes returning the 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)

Key Components of HSI Implementation

- From review of lessons learned in the DoD, NASA, and other environments, the following are key components needed to implement HSI within systems engineering lifecycle processes
    - The first of these is the ***HSI Plan***
    - The second is the ***HSI Team***
    - The third is the use of ***metrics*** to track progress



Component 1: HSI Plan

HSI PG p. 2

HSI PG App. A

- 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 could be a part of the Program/Project SEMP, could be a standalone document aligned with the SEMP, or could be part of 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

HSI PG
p. 4-5

- 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, and to facilitate resolution of HSI related issues during the lifecycle
  - This is not an oversight role as much as it is a collaboration role
  - The team members typically engage in working groups, IPTs, and control boards to help solve problems, identify needs for HSI related domain expertise
  - They identify human related cost drivers which increase life cycle costs or decrease system performance, and guide solutions

Component 2: HSI Team *(continued)*

HSI PG
p. 4-5

- The HSI Team ensures the most effective, efficient, and affordable design possible through tradeoff studies within and between domains, disciplines, and/or systems
- The members of the team also:
  - Identify, resolve, and track HSI related issues as the program progresses
  - Review relevant system documents during major design reviews.
  - Ensure Test and Evaluation (T&E) efforts demonstrate whether HSI requirements have been met
  - Track entry and exit criteria for each lifecycle phase, review, and milestone
  - Update the HSI Plan as the program or project proceeds through the SE lifecycle

Note: While the HSI Team may include specific domains or disciplines (e.g., Safety, HFE), it does not replace or assume ownership of the domain, organization, or function.

Component 3: Metrics

HSI PG
p. 4-18

- 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

An Example of an HSI Process Checklist *(1 of 3)*

Action	Assessment
❑ Determine scope of planning effort and appoint HSI Lead	• How does it compare to other programs projected HSI effort?
❑ Initiate HSI Planning Activities ❑ Coordinate with PM ❑ Develop a meeting schedule ❑ Develop planning assumptions	• Have you coordinated for external support that may be required? • Have you reviewed relevant NASA HSI standards, requirements, and other relevant documents?
❑ Draft HSI Plan	• How does it compare with previously developed HSI Plan? • Are the releases per NPR 7123.1B schedule?

An Example of an HSI Process Checklist *(2 of 3)*

Action	Assessment
❑ Form HSI Team ❑ Develop a charter to clearly identify roles & responsibilities ❑ Assign HSI domain analysis leads	• Team stood up by SRR, per NPR 8705.2B? • Membership includes applicable and appropriate roles compared to previous similar projects?
❑ Support development of ConOps ❑ Identify human elements, goals ❑ Collaborate on feasible concept	• Detailed enough to support architecture, function allocation, and requirements? • Baselined in Phase A?
❑ Identify HSI Domains needed relevant to requirements	• Identified all specialty areas and reviewed literature/lessons learned? • Contacted necessary representatives?

An Example of an HSI Process Checklist *(3 of 3)*

HSI PG
App. B

Action	Assessment
❑ Impact System Design ❑ Assess total system performance characteristics and tasks ❑ Address HSI in relevant portions of formal plans, test, and evaluation ❑ Create constraints and requirements for logistics support, program resources and training plans ❑ Conduct trade-offs of design approaches based on targeted metrics (e.g. crew time) ❑ Propose solutions for human-systems and subsystems issues ❑ Formulate plans to perform HSI review/assessments on hardware/software revisions that add/delete/defer capability not addressed in the capability documents ❑ Identify checkpoints to validate to ConOps	• Has the function allocation been completed? • Has the total system approach (hardware, software, human) been considered? • Have all prior analytical steps been completed? • Are all program relevant HSI domains being represented? • Are Measures of Effectiveness associated with HSI domains been documented?

A ‘by-Domain’ checklist is provided in the HSIPG, Appendix B.

Scaling HSI

HSI PG
p. 4-2

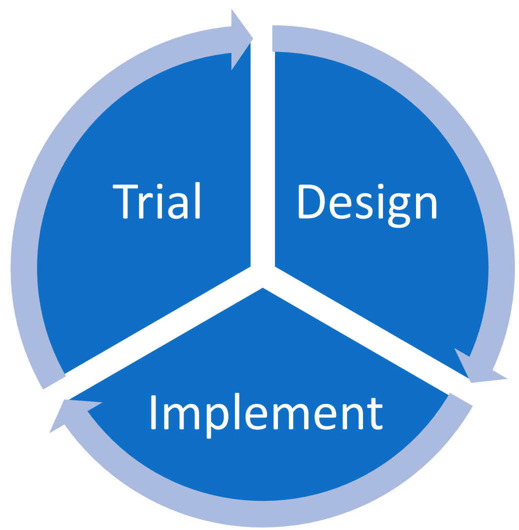
- Recent agency emphasis has been on small-scope and/or advanced technology development projects
  - This offers an opportunity for early inclusion in pre-phase A activities (i.e., early conceptual design)
  - ***Examples:*** *Advanced Exploration Systems (AES) projects such as Deep Space Habitat, Autonomous Mission Operations, and other engineering activities (e.g., Human Integrated Vehicles Environments, Virtual Windows, e-Textiles)*
- 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

Scaling the Process

The core process of user-centered design is the same for any size project / program

- Analyze user's goals and tasks
- Create design alternatives
- Evaluate options
- Implement prototype(s)
- Test / Validate
- Refine



The Importance of ConOps Development

HSI PG
p. 4-14

- One well-recommended HSI activity which NASA does implement is concepts of operations (ConOps) development
  - The earlier the better!
  - Helps to drive the design based upon mission success criteria and prior operational knowledge
- Provides guidance for
  - Development of the system
  - Function allocations to hardware, software, and humans
  - Verification and validation of stakeholder goals and requirements
- The ConOps is a view of the system from the perspective of the users
  - Requires the input of many disciplines and subject matter experts (often becoming the HSI team)
- The ConOps is used repeatedly to ensure that the system will meet the mission goals
- Scope may include maintenance, ground handling, and off-nominal scenarios

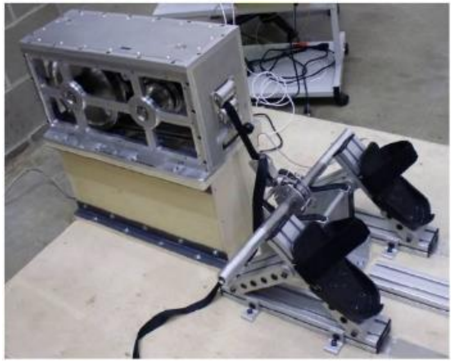
HSI-based Requirements

HSI PG
p. 4-17

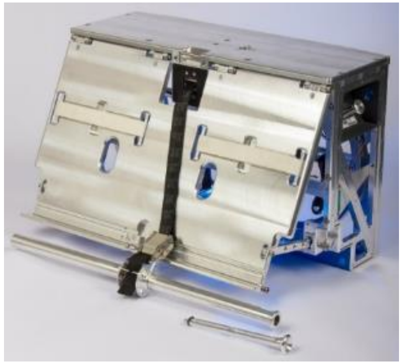
- Ensures that human considerations are included in system design
  - The ultimate "tool" for impacting system design and performance
  - Often have cost and schedule implications
- Typically derived from ConOps via functional analysis of the
  - Mission
  - Scope
  - Relevant HSI Domains
  - Human Risk Mitigation
- Can also come from Standards and Institutional Docs
  - HFE standards, NASA-STD-3001 Vol. 1 and 2
    - Medical Operations Requirements Document (MORD) derived from Vol. 1
    - Human Systems Integration Requirements (HSIR) for human-rated programs, from Vol. 2

Refer to the HSI PG for more guidance and references

NASA Example: HSI Requirements Improve Results!



MPCV Exercise Device (Flywheel)



2009 Prototype for Constellation
- No real requirements
- No real ConOps
- 80+ lbs.
- No power to operate*
- No cabin thermal impact*
- Little to no SME input or HSI focus
- Received a low score in trade matrix (same as 2015 flight criteria)

*Due to these minimal vehicle impacts, got to try again

2015 Prototype for MPCV/Orion
- Flight requirements provided (draft)
- DRM and ConOps provided
- 29 lbs.
- No power to operate
- No cabin thermal impact
- Ergonomically designed for MPCV/Orion
- All accessories store inside unit
- Collaborative Design with SME input
- Received the highest score in trade matrix

Human-Centered Trade Studies

HSI PG
p. 4-7

- Stakeholder value drives engineering trade space
  - Reducing cost is not always a top priority
  - Removing risk, operational efficiency and compliance, crew time (examples)
- Creating human-centered criteria moves you from technology-driven solutions to task-driven solutions

Example HSI Trade Study Criteria

Trade Study	Example Criteria
Crew-operated Instrument or Medical Device (multiple sources)	• Portability: attach points, handles, size, cabling • Power: battery management logistics, cabling, heat, noise (fans), interface availability and type • Calibration: crew time, periodicity, complexity, accuracy • Complexity to operate (subjective assessment) • Display readability
Net Habitable Volume (multiple designs)	• Proposed Crew size > consumables, life support, etc. • Proposed Design Reference Mission (DRM) timeline • Vehicle size constraints

HSI Trade-off Examples

- Sometimes a consideration is so clear it becomes a “killer trade”

Example Topic	Trade-Off	Considerations (HSI)
Hand-held Device	Portability: attached power cable vs. replaceable batteries	• Battery Logistics cost • Crew time impact for replacing batteries • Battery run time
Line/Orbital Replacement Unit (LRU/ORU)	Testability: built-in diagnostic self-test vs. ready spare on-orbit	• Mass, power, complexity, comm. for added capability • MTBF; R&R periodicity • MTTR; R&R on-orbit time • Criticality of function
Emergency Egress and post-landing survival in sea states	Cabin temperature vs. acoustic noise vs. suit and vehicle design vs. crew health and performance	• Vehicle constraints: battery life, communications, life support • Landing ConOps • Human Health constraints
Water Sampling Device Complexity	Crew time vs. cost of automated or autonomous system	• Cost of design • Crew time impact for repetitious operation • Design for back-up manual mode

Final Exercise

- Use the Evaluation Checklist handout to assess a current project against a short list of HSI process criteria / goals.

5 minutes

HSI Process Checklist (short version) for Project Self-Evaluation Exercise

Topic	Evaluation of Current Project > Action Needed	Related Assessments
Determine scope of planning effort and appoint HSI Lead		How does it compare to other programs projected HSI effort?
Initiate HSI Planning Activities • Coordinate with PM		Have you coordinated for external support that may be required? Have you reviewed relevant NASA HSI standards, requirements, and other relevant documents?
• Develop a meeting schedule		
• Develop planning assumptions		
Draft the HSI Plan		How does it compare with previous HSI Plan? Per NPR 7123.1B schedule?
Form HSI Team • Develop a charter to clearly identify roles & responsibilities		Team stood up by SRR? Membership includes applicable and appropriate roles compared to previous similar projects?
• Assign HSI domain analysis leads		
Identify HSI Domains per requirements		Identified all specialty areas and reviewed literature/lessons learned?
Support development of ConOps • Identify human elements, goals		Detailed enough to support architecture, function allocation, and requirements? Baselined in Phase A?
• Collaborate on feasible concept		
Impact System Design • Assess total system performance characteristics and tasks		Has the function allocation been completed? Has the total system approach (hardware, software, human) been considered? Have all prior analytical steps been completed? Are all program relevant HSI domains being represented? Are Measures of Effectiveness associated with HSI domains been documented?
• Address HSI in relevant portions of formal plans, test, and evaluation		
• Create constraints and requirements for logistics support, program resources and training plans		
• Conduct trade-offs of design approaches based on targeted metrics (e.g. crew time)		
• Propose solutions for human-systems & subsystems issues		
• Formulate plans to perform HSI review/assessments on hardware/software revisions that add/delete/defer capability not addressed in the capability documents		
• Identify checkpoints to validate to ConOps		

Version 1.0

Useful HSI Related Links

- HSI Practitioner’s Guide
  - Google “HSI Practitioner’s Guide” to download a pdf of the document from NTRS
- HSI ERG: http://collaboration.jsc.nasa.gov/iierg/HSI/SitePages/Home.aspx
  - Links to SE Handbook, meetings, community, etc.
- Human Systems Academy: http://sashare.jsc.nasa.gov/hsa/
  - Future Training courses for Practitioners (TBD)
- Naval Postgraduate School HSI Program: www.nps.edu/or/hsi
  - They have online training and certification programs available for those interested
  - They also offer a full master’s degree in HSI (2 years of coursework)