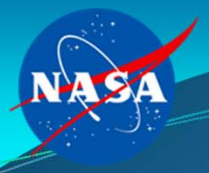


Human Systems Integration (HSI) at NASA

NDIA, 9/11/12

Presenters:

- David Fitts
  - –Acting Deputy Chief, Human System Engineering Division
- Dr. Jennifer Rochlis, PhD
  - –Lead, Human Systems Integration

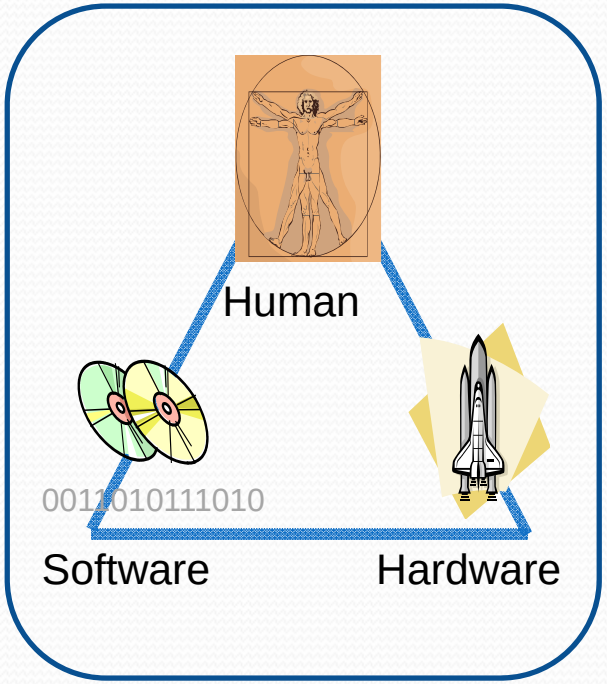
Presentation Overview

- **NASA & Human Systems Integration (HSI)**
- **HSI Domain Standards & Requirements**
  - **NASA-STD-3001: Space Flight Human Systems Standards (2 vols)**
  - **Human Integration Design Handbook**
  - **Constellation Program HSI Requirements**
- **HSI Processes**
  - **Commercial HSI Processes document**
  - **HSI Processes document**
- **HSI Insertion in Systems Engineering**
- **HSI Metrics**

NASA & HSI

There is currently no formal Agency-wide recognition of HSI but there's awareness and discussion

- I.e., there's no mandate equivalent to DoD Instruction 5000.02
- This presentation relates the current state of DoD-like HSI at NASA



At the Johnson Space Center (JSC) and other NASA Centers, there are advocates for DoD-like HSI models for application to space missions

- HSI domains exist: Environmental Factors, Human Factors, Occupational Health, Training, Habitability, Countermeasures, Survivability
  - Manpower & Personnel are not currently formalized the same as the others

NASA Human Spaceflight Programs

Apollo

(1963-1972)

Space Shuttle

(1981-2011)

International Space Station

(1998-present)

Constellation

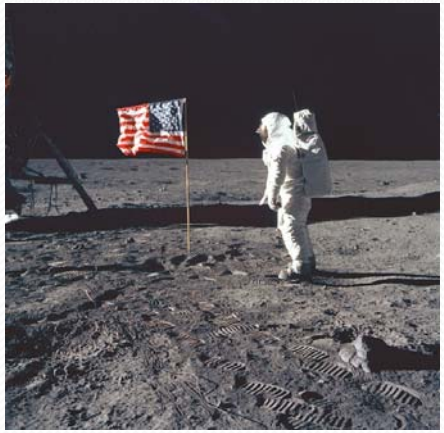
(2005-2010)

Apollo

1963-1972

The Apollo Program focused on successful completion of a mission that utilized innovative technologies

- Clearly, the human was an important element of the Program



There was significant human/system interaction with the crew in all elements of design

- Significant human-in-the-loop testing and evaluation of systems, but standards had not yet evolved

Space Shuttle

1981-2011

By the time of the Space Shuttle Program, vehicle design was handled more like today's acquisition contracts and less as an R&D endeavor

- Prime Contractor held principal responsibility for design & integration

Human System lessons began to be captured in design standards that evolved from Apollo, Gemini, Mercury

NASA Standards for HSI Domain Knowledge

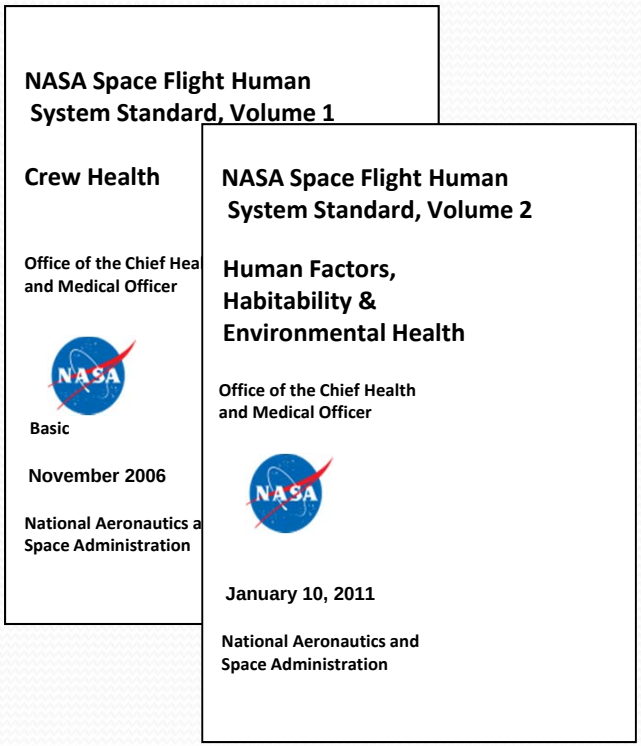
Human/system experience for development of vehicles is captured in NASA-STD-3001, "Space Flight Human System Standards"

- Volume 1: Crew Health
- Volume 2: Human Factors, Habitability & Environmental Health

Evolved from…

NASA-STD-3000, Man Systems Integration Standards (1985)

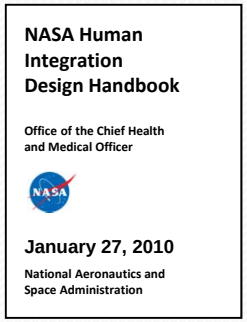
- Initiated between the Shuttle and Station programs



Supported by…

NASA Human Integration Design Handbook (2010)

- 1136 pages of information
- NASA's databank of HSI domain lessons learned



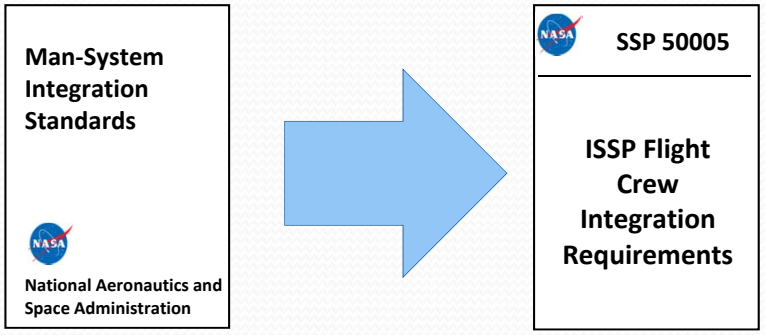
Standards-to-Requirements

Each new human spaceflight program turns NASA-STD-3001 into their own program-specific set of requirements

- Written into development contracts & sub-contracts as "SHALLS"
- This "Standards-to-Requirements" process was followed for the ISSP & CxP

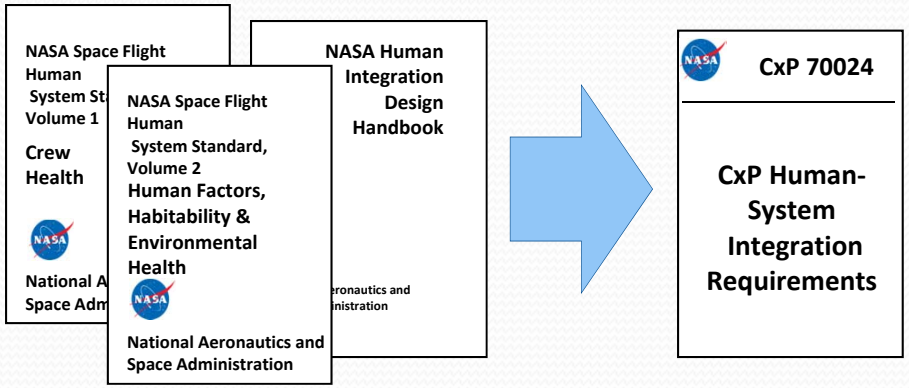
International Space Station:

(1998-present)



Constellation:

(2005-2010)



This process is required by NASA Procedural Requirements:

- NPR 8705.2, Human-Rating Requirements for Space Systems
- NPR 7120.11, Health & Medical Technical Authority Implementation

Case Study: HSI domain standards & requirements documents are updated and ready for NASA's next major mission

Standards-to-Requirements Examples

Example Human Factors Standard (from NASA-STD-3001):

- 10.3.2.6 Display Navigation [V2 10043]

  Display navigation shall allow the crew to move within and among displays without loss of situational awareness in a timely manner

---

Example Human Factors Requirement (from Constellation):

- 3.6.4.2.1 Location within the Display Hierarchy

  Displays shall provide the crew with the location of the current display within the display hierarchy

Example Habitability Requirement (from Constellation):

- 3.5.7.3 Trash Management Contamination Control

  The trash management system shall prevent the release of trash into the habitable environment

Example Environmental Requirement (from Constellation):

- 3.2.4.1.1 Crew Exposure to Rate of Change of Acceleration

  The system shall prevent the crew from being exposed to a rate of change of acceleration of more than 500 g/s during any sustained acceleration event

HSI Processes

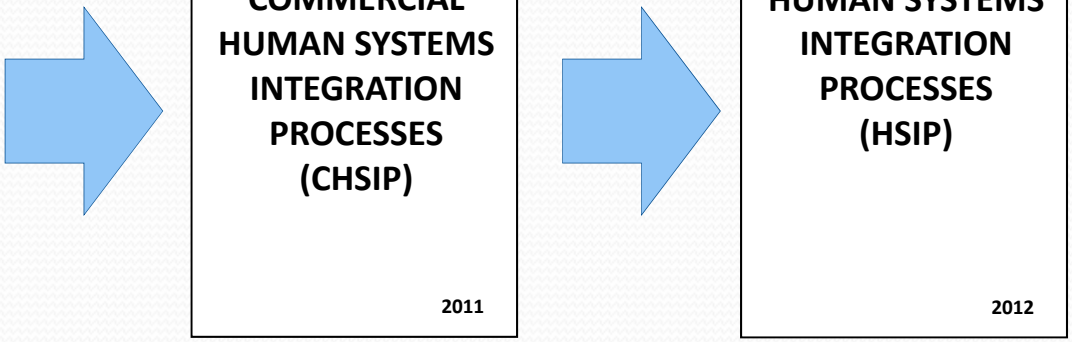
Current program emphasis on requirements hasn't been very accepting of including processes in lieu of requirements

- But often there's no simple "Shall" answer to complex design issues

Case Study: For the current Commercial Crew Program (CCP) the first HSI Processes document was generated and is in process of becoming a generic "HSIP" applicable to all future programs

Example Processes:

- Task Analyses
- Workload Evaluation
- Human Error Analyses
- Design for Human Physical Characteristics, Capabilities, and Population Variation
- Acoustic Noise Control
- Handling Qualities Evaluation
- Crew Survivability Assessment
- etc.



HSI Processes (cont'd)

Example Process: Net Habitable Volume

- New space vehicles & habitats must address this
  - Only surfaces as an issue every 15-20 years
  - Constraints:
    - Systems: Minimize mass, volume, power, etc.
    - Humans: Maximize accommodation of human needs, including psychological, social, fitness, health, ability to perform functions, etc.
  - Process:
    - **Process**: Record history, lessons learned, "How to", rationale, and challenges
      - Each new iteration adds new data, expanding the knowledge base. Processes are living!

NASA's Changing Context

NASA's newest human flight program--the Commercial Crew Program (CCP)--follows the Standards-to-Requirements model

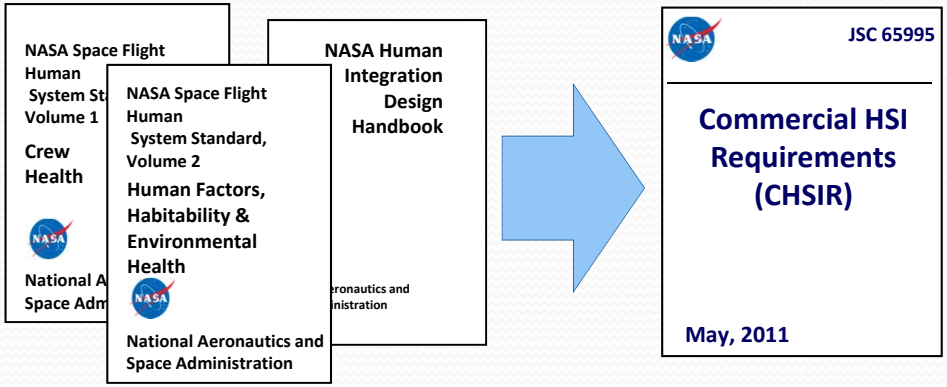
- Next NASA human flight project turns to the private sector for innovation
  - Goal is to lower the cost to Low Earth Orbit (LEO)
  - First commercial cargo flight to ISS docked on-orbit on May 25, 2012

However, the end product is a recommendation, not requirements

NASA-STD-3001
& the HIDH

-- generated the --

Commercial HSI
Requirements

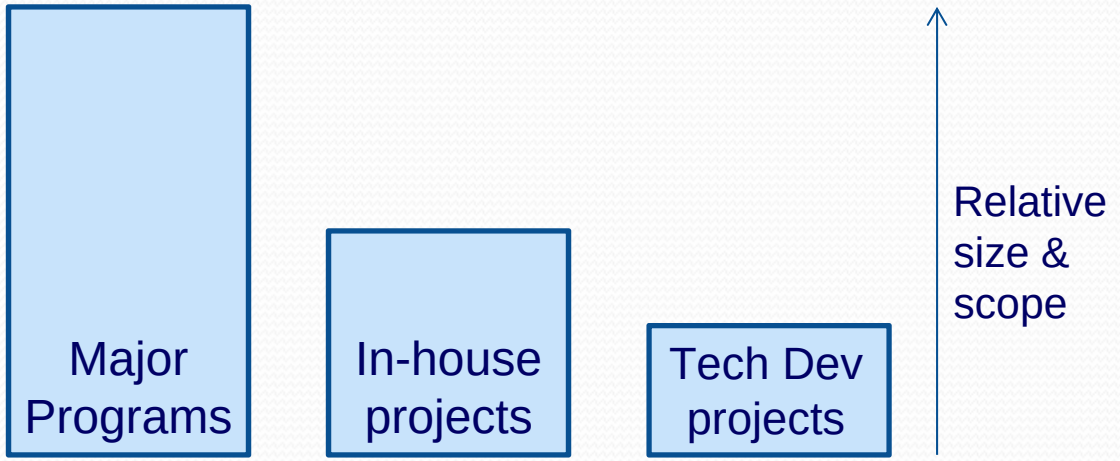


Leaving the NASA HSI community to investigate alternate, durable methods for including HSI in programs and projects

NASA's Changing Context (cont'd)

Large programs rely on requirements, but NASA will be focused on smaller projects until the next major program is announced

- Methods for HSI domain involvement will be tailored to projects' size & scope
- Major programs: Many methods for HSI engagement,
- Small projects: HSI's range of options for engaging narrows



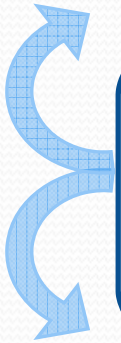
HSI…

	Major Programs	In-house projects	Tech Dev projects
Requirements:	✱		
Standards:	✱	(✱)	
Processes:	✱	✱	(✱)
Systems Engineering:	✱	✱	(✱)
Participation in Design:	✱	✱	✱

Towards NASA HSI…

Integration of HSI domain requirements into NASA human spaceflight has been a success, but there's more to be done…

1) **Infuse HSI into NASA Systems Engineering**
   - Not just standards & requirements, but processes



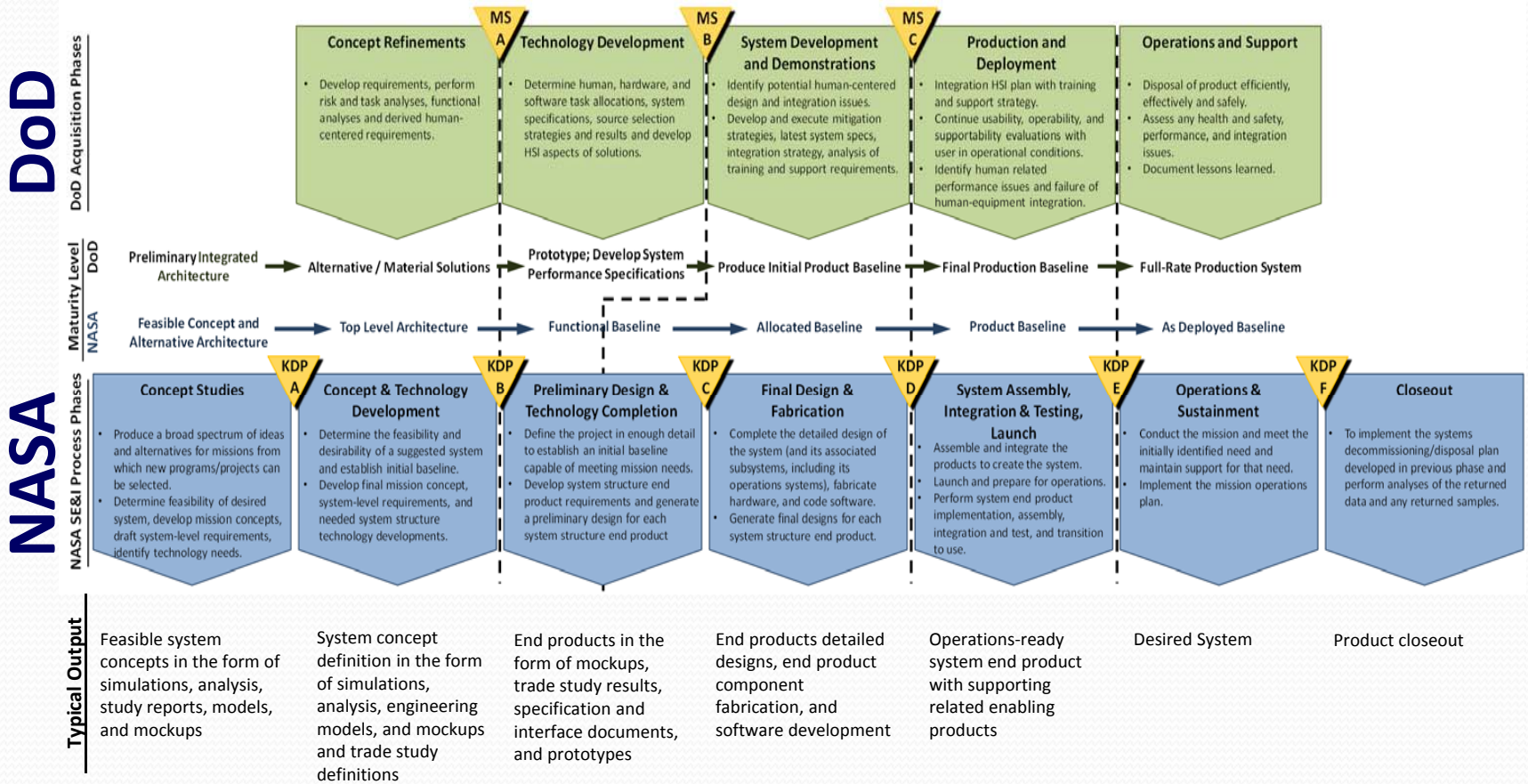
Identify HSI metrics & integrate them into SE
- Move beyond the current focus on crew interfaces
- Include Manpower, Personnel, & Training
- Address logistics, maintenance, repair, & ground control

2) **Prove the life-cycle cost-savings benefits of HSI**

HSI Insertion into Systems Engineering

NASA's Systems Engineering process is similar to the DoD's

- Though we know of differences in both the SE and acquisition processes

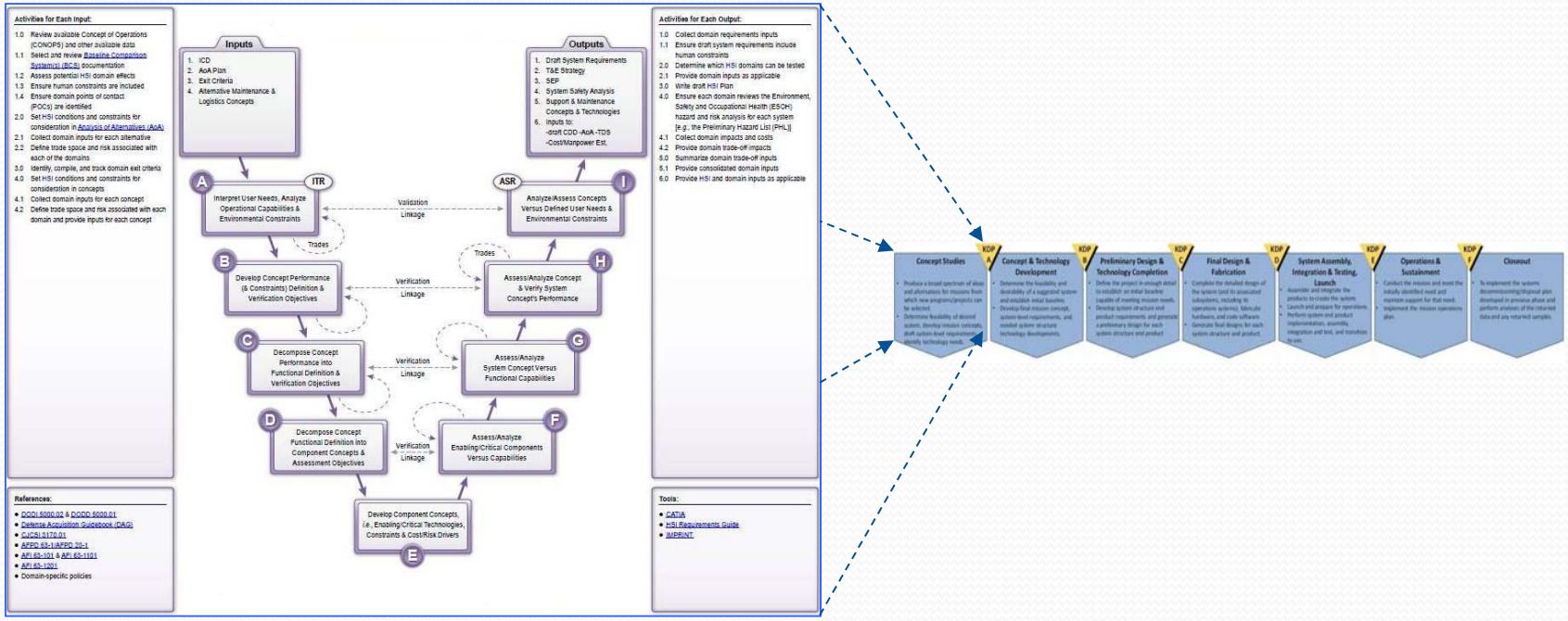


HSI Insertion into Systems Engineering (cont'd)

NASA seeks to integrate HSI processes & metrics into NASA SE

- Currently gathering examples from other orgs that have pursued this
  - E.g., NDIA's Systems Engineering Division, HSI Committee
  - E.g., Air Force, Other DoD, Dept of Homeland Security, FAA, etc.

Case Study: This effort is a work in progress

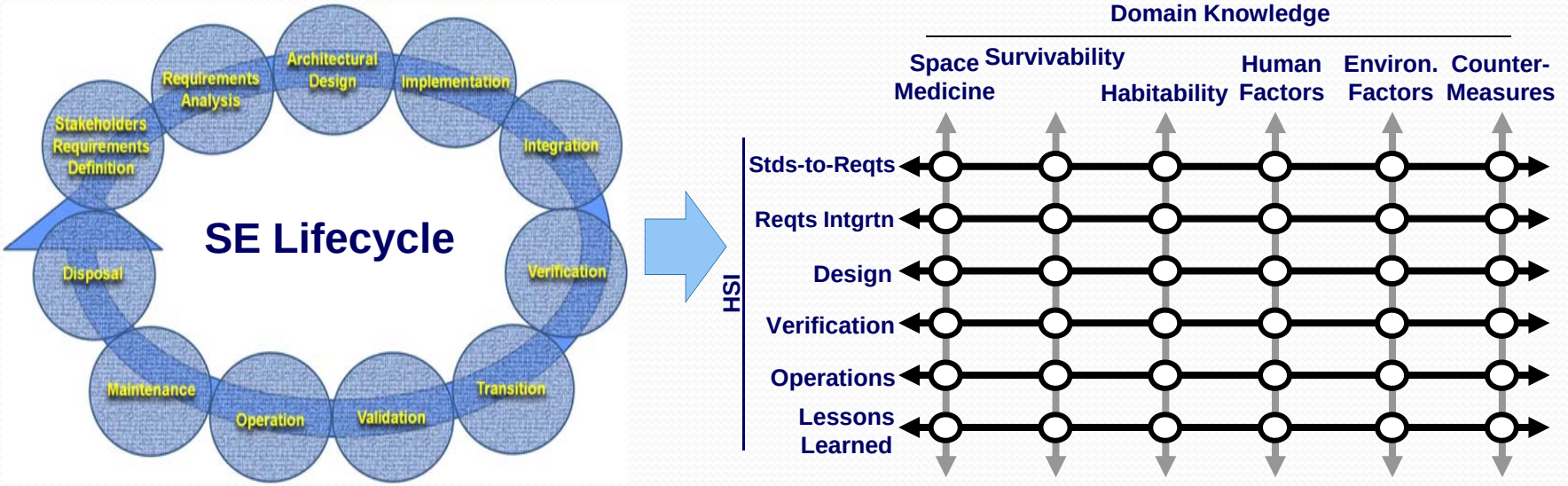


Identification of appropriate metrics is key!

HSI Insertion into Systems Engineering (cont'd)

Case Study: NASA is developing an HSI-into-NASA-Systems Engineering roadmap. It acknowledges that different cultures (and their processes) come to bear during the life-cycle

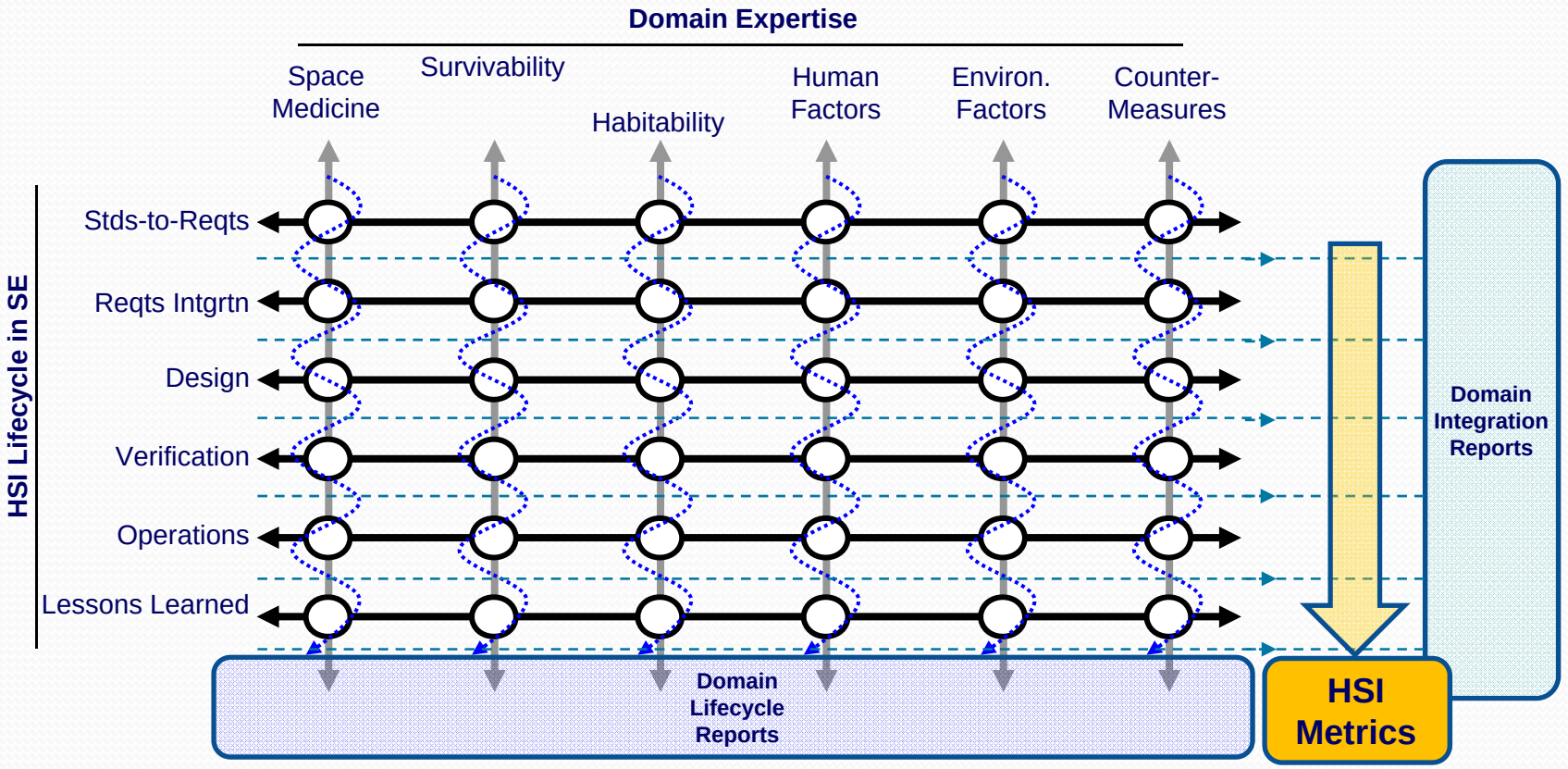
- E.g., Program Managers tightly control Stds-to-Reqts & Verification processes
- But Design & Validation are less tightly controlled processes with different players
- HSI-in-SE is an array of processes, policies, products, tools, etc. No "one size fits all"
- Initial policy work has been proposed and is under review--e.g., "PMs shall deliver an HSI Management Plan as part of their Systems Engineering Management Plan"



HSI Metrics

However, metrics can and must provide a unifying thread

- Essential to staying "on point" to achieving HSI Goals
  - Life-cycle cost savings
  - Safer, more efficient/effective total system (human+hardware+software) performance
  - Focused on HSI domains relevant to NASA's mission



Challenges of HSI Metrics

Example: Metrics ownership

- Desired outcome:
  - "The Program Manager SHALL minimize personnel service time, personnel training time, and equipment needed for planned and anticipated maintenance and repair operations to the system"
- Pushback:
  - "The PM is responsible for delivering a product. NASA is responsible for designing and implementing maintenance procedures. The PM can't be held accountable for this"
  - "'Minimize' is not an acceptable requirement"
- The Need: *What metrics can be cited that Development Program Managers feel they can responsibly sign up to owning?*

Challenges of HSI Metrics (cont'd)

Example: Predictive metrics

- Desired outcome:
  - "The system SHALL be designed to require no more than one hour of personnel time per month for planned maintenance"
- Pushback:
  - "How would I know this? As the designer I'm not responsible for designing maintenance procedures, selecting maintenance personnel, determining personnel skill levels, etc. Given an option between two design options, what tool could predict this outcome for me?"
- The Need: *What tools can be generated that can predict HSI performance metrics outcomes during the earliest, phases of conceptual design?*

Challenges of HSI Metrics (cont'd)

Example: Key signifiers

- Desired outcome:
  - "The system SHALL be designed to be serviced, repaired, and maintained using only the tools in the standard program toolkit"
  - PM/Designer: "This I understand and will attempt to achieve!"
- Pushback:
  - What evidence can HSI researchers and technologists cite that this metric will solve the problem of containing ops expenses?
- The Need: *Which metrics have an evidence base that is traceable to life-cycle costs?*

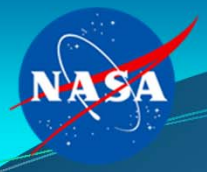
Challenges of HSI Metrics (cont'd)

In all examples…

- *How do I know the resources (particularly MPT) needed to operate and maintain the system long before I build it?*
  - *"Reverse engineering" past examples?--e.g., why couldn't Shuttle fly 40 times/year?*
- *Where are the sensitivities? Which design decisions impact ops era resources?*

In the end, we're all pursuing the "Holy Grail" of HSI…

- I.e., prove the value-added of HSI



Backup

Socializing HSI

To promote HSI and to cross organizational lines, NASA/JSC has established HSI socialization forums:

HSI Employee Resource Group (ERG):

- "ERGs are voluntary grassroots groups formed by employees around a characteristic or affinity"
- Five NASA/JSC ERGs were approved:
  - African American ERG
  - Asian Pacific American ERG
  - Hispanic ERG
  - Lesbian, Gay, Bisexual, Transgender (LGBT) ERG
  - Human Systems Integration (HSI) ERG

Purpose of the ERGs:

- Help JSC recruit new talent — "Recruiting"
- Help JSC keep its existing talent — "Onboarding"
- Help JSC move forward — "The Business Case"

Socializing HSI (cont'd)

HSI domains are spread across multiple NASA organizations. The HSI ERG promotes cross-org communication and advances a common vision of NASA HSI

Socializing HSI (cont'd)

A Human Systems Academy has been formed and is developing an HSI training curriculum

- May also develop an HSI certification process
- There's been initial discussion on establishing an HSI Competency--i.e., a recognized HSI career development path
  - The ERG is trying to broaden hiring for under-represented HSI domain skills

A multi-org JSC Systems Engineering Forum HSI Splinter has been established to propose & promote technical changes to infuse HSI into the NASA Systems Engineering process

- Similar to saying, "…infusing HSI into NASA acquisition processes"

A multi-Center HSI Steering Committee is being chartered

- Most Centers have signed on. Reports to the HQ Office of Chief Engineer
- Will serve as the first formal Agency-wide HSI group
- Helps vet HSI into Agency processes--e.g., NASA Systems Engineering

NASA-STD-3001: Space Flight Human Systems Standards

Link, Vol. 1: https://standards.nasa.gov/documents/detail/3315622

Table of Contents: Vol. 1, Crew Health

- Levels of Medical Care
- Standards for Human Performance
- Health & Medical Screening, Evaluation, and Certification
- Medical Diagnosis, Intervention, Treatment, and Care

Link, Vol. 2: https://standards.nasa.gov/documents/detail/3315785

Table of Contents: Vol. 2, Human Factors, Habitability, Environmental Health

- Human-Centered Design Process
- Physical Characteristics and Capabilities
- Perception and Cognition
- Natural and Induced Environments
- Habitability Functions
- Architecture
- Hardware and Equipment
- Crew Interfaces
- Spacesuits

Human Integration Design Handbook (HIDH)

Link: http://ston.jsc.nasa.gov/collections/TRS/_techrep/SP-2010-3407.pdf

Table of Contents:

- Application of the HIDH to Systems Design & Development
- Anthropometry, Biomechanics, and Strength
- Human Performance Capabilities
- Natural and Induced Environments
- Habitability Functions
- Architecture
- Hardware and Equipment
- Crew Interfaces
- Extravehicular Activity (EVA)
- Operations
- Ground Maintenance and Assembly

CxP Human System Integration Requirements (HSIR)

Link: ???

Table of Contents:

- Anthropometry, Biomechanics, and Strength
- Natural and Induced Environments
- Safety
- Architecture
- Crew Functions
- Crew Interfaces
- Maintenance and Housekeeping
- Information Management
- Ground Maintenance and Assembly
- Extravehicular Activity (EVA)

Commercial Human System Integration Processes (CHSIP)

Link: http://www.nasa.gov/centers/johnson/slsd/resources-links.html

Table of Contents for the generic HSIP:

1. User Task Analysis
2. Usability Evaluation
3. Workload Evaluation
4. Human Error Analysis
5. Design for Crewmember Physical Characteristics and Capabilities
6. Handling Qualities Evaluation
7. Acoustic Noise Control Design
8. Radiation Shielding Design
9. Functional Volume Design
10. Crew Survivability Assessment
11. Metabolic Loads and Environmental Control Life Support System Design
12. Display Format Design
13. User Interface Labeling Design
14. Occupant Protection Design
15. Design for De-conditioning
16. Design for Mitigation of DCS Risk
17. Meal and Food Planning
18. Legibility Evaluation

Note: The generic HSIP is not yet baselined