National Aeronautics and Space Administration

NASA's Human Systems Integration (HSI) Community of Practice (CoP)

Under Secretary of Defense for Research and Engineering

Human Systems Community of Interest Annual Meeting
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Kimberlee Prokhorov
Former NASA HSI CoP Chair, FY 2021-2022
Office of the Chief Health & Medical Officer HSI CoP Representative

NASA's HSI Evolution

- **1965: MSFC-STD-391**, **Human Factors Engineering Program**, established minimum human factors program requirements to promote maximum effectiveness and reliability of the man as a system component.
- **1966: MSFC-STD-267A**, **Human Engineering Design Criteria** published to present human engineering design principles and practices to be used by engineers in designing equipment for achievement of satisfactory performances of operator, maintenance, and control personnel, to reduce skill requirements and training time, to increase reliability of personnel-equipment combinations, to provide a basis for design standardization of large earth-launch booster systems.
- **1970s-1980s: NASA advanced aviation safety and matured concepts in crew resource management.**
- **1974: MSFC-STD-512 Man/System Requirements for Weightless Environments**
- **1987: NASA-STD-3000 Man-System Integration Standard**
- **2012: NPR 8705.2B**, **Human-Rating Requirements for Space Systems**, was updated to include human systems integration.
- **2013: NPR 7123.1B**, **NASA Systems Engineering Processes and Requirements**, was updated to Revision B, to include HSI as a part of overall SE.
- **2014: NASA/TP-2014-218556, Human Integration Design Processes (HIDP)** released, which captures NASA human engineering and HSI lessons learned to supplement standards and requirements.
- **2015: NASA-STD-3001, NASA Space Flight Human-System Standard, Volume 2: Human Factors, Habitability, and Environmental Health**, was updated with a new requirement for human-centered design. Currently applies to human spaceflight and not to other NASA programs, such as aviation and uncrewed space exploration.
- **2015: NASA/SP–2015-3709, NASA HSI Practitioner's Guide (HSIPG),** was published defining NASA HSI domains. This initial HSI guide provides much-needed guidance on HSI team responsibilities, activities, and products, along with guidance on writing a HSI Plan. The HSIPG set the bar as a guiding document for primarily human spaceflight missions. Currently under revision to the NASA HSI Handbook.
- **2017: NASA HSI Tiger Team formulated via APMC action** to assess HSI technical gap and recommend forward actions.
- **2019: APMC directed OCMO and OCE to work on 7120 policy updates for HSI** to be included in new procurements for projects/programs and **directed establishment of a HSI Community of Practice**
- **2020: HSI CoP Charter established**.

NASA's HSI Evolution

- Historically NASA has some "Flagship" human space missions, that have enjoyed significant HSI consideration.
- Progress made in the last 5 years with increased HSI in Aerospace.
- NASA's HSI growth and focus areas are two-fold:
  - Increasing implementation of HSI in non-human spaceflight projects
  - Ensuring HSI is captured in commercial contracts

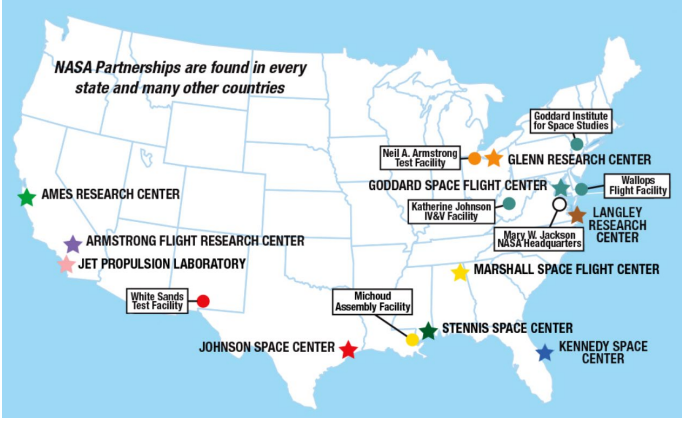
NASA's HSI CoP Core Structure

Chartered by all 3 Technical Authorities (TA)

2 Representatives from each TA
Of these 6:
1 Chair and 1 Deputy Chair

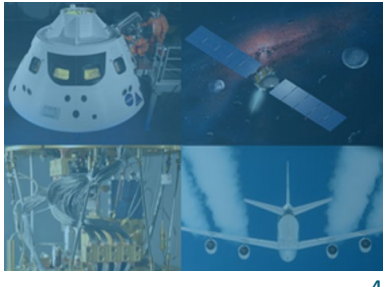
Note: CoP also includes General Members across Agency

10 NASA Centers: 2 Representatives from each center



5 Mission Directorates (MD) : 1 Representative from each MD

- Aeronautics Research
- Exploration Systems
- Space Operations
- Science
- Space Technology

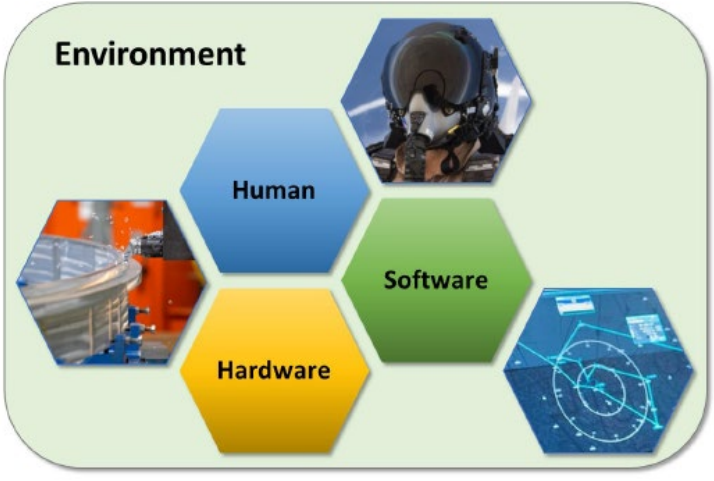


NASA's HSI Definition & CoP Purpose

A **required interdisciplinary integration of the human** as an **element of the system** to ensure that the human and software/hardware components cooperate, coordinate, and communicate effectively to **perform a specific function or mission successfully**.

Scope:

- HSI is **applied throughout the mission lifecycle** from pre-formulation and acquisition through design, development, operations, maintenance, and decommissioning.
- HSI is **applicable to both crewed and uncrewed missions, and across all Mission Directorates**.



HSI CoP Purpose:

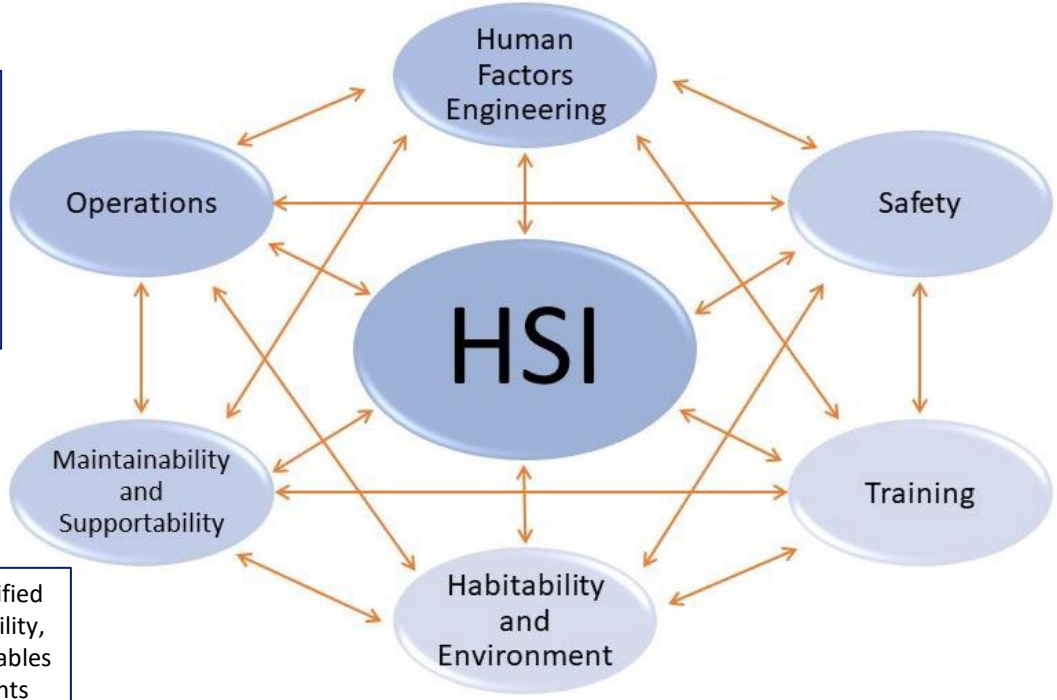
- Share HSI expertise, lessons learned, and best practices of all HSI domains across the Agency.
- Help promote HSI advocacy by communicating the benefits of HSI to Program/Project Managers, Systems Engineers and Stakeholders.
- Help improve/advance the existing practice of HSI across the Agency based on Agency policy and guidance.

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

NASA's Human Systems Integration Domains

Designing and evaluating system interfaces and operations for human well-being and optimized safety, performance and operability, while considering human performance characteristics as they affect and are affected by environments and operating in expected and unpredicted conditions

Full life-cycle engagement of operational considerations into the design, development, maintenance and evolution of systems and organizational capability to enable robust, cost-effective mission operations for human effectiveness and mission success



Implementation of safety considerations across the full life cycle to reduce hazards and risks to personnel, system, facilities and mission

Designing for full life cycle and simplified maintenance and accessibility, reliability, optimized resources, spares, consumables and logistics given mission constraints

Ensuring system integration with the human through design and continual evaluation of internal/external living and working environments necessary to sustain safety, human and mission performance, and human health

Design and implementation of effective training methods and resources to maximize human retention, retrieval and transfer, proficiency, and effectiveness to successfully accomplish expected an unexpected mission tasks, properly operate, maintain, and support the system and mission

Community of Practice:
FY2021-2022 Summary and Metrics

NASA human systems integration

Membership

- January 2021 – 21 people
- November 2021 – 48 people
- December 2021 – 100 people
- January 2022 – 108 people
- September 2022 – 136 people
- October 2022 – 142 people

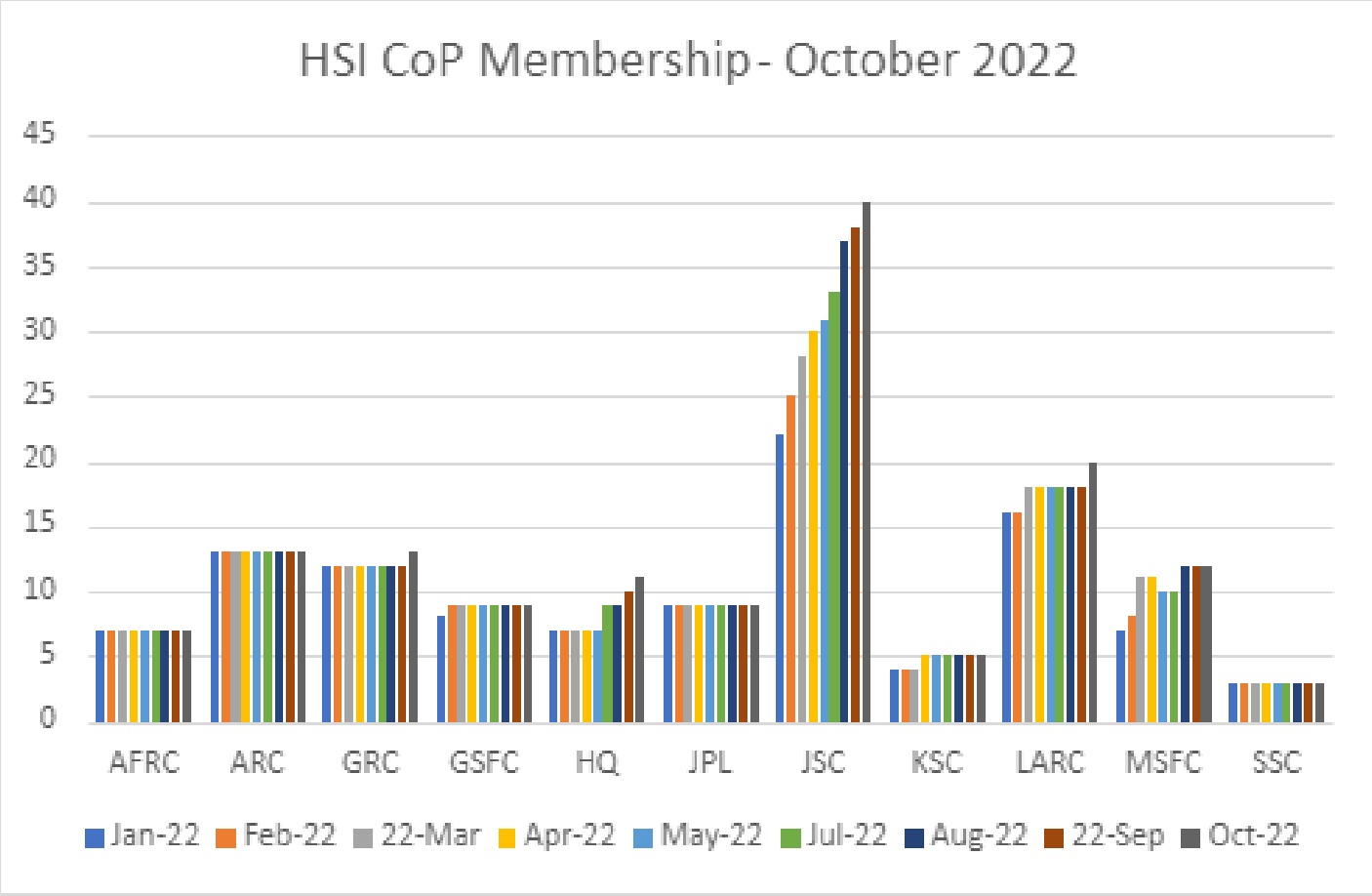
FY2021: HSI CoP Website Established & Opened Community Across Agency
https://nen.nasa.gov/web/hsi

HSI Handbook Published November 2021
Includes HSI Plan template to support NPR policy updates

HSI CoP Kick-off Agency-wide November 2021
Reached ~210 people

HSI 101 Training Developed
- Soon to be Satern class for Agency
HSI Lead Curriculum – In work

NASA's HSI CoP Membership Growth



FY21-22 HSI CoP Special Topics

- **Maximum Work Time (NPR 1800.1) and relation to HSI**
  - Jade Spurgeon, MD, Director of Health and Medical Systems.
- **Implementing Human Systems Integration in Aeronautics: Lessons Learned from the X-57/Maxwell and Electrified Power Train Flight Demonstrator (EPFD) Projects**
  - Stephanie Blake, Human Systems Integration Lead, X-57 & Electrified Power Train Flight Demonstrator (EPFD)
- **Closing the QA Expert Competency Gap Using Modeling and Digital Assistants**
  - Jeannette Plante, Quality Engineering Technical Fellow
- **Validating novel objective metrics of human capabilities and limitations to support HSI-focused standards, requirements, and designs.**
  - Lee Stone, NASA Senior Researcher, HSI; Principal Investigator, Visuomotor Control Laboratory
- **Pilot Breathing Assessment TI-18-01320 Final Report**
  - NESC Assessment Re-presentation with Live Q&A with Kellie Kennedy
- **HSI in SMD: Mars Rovers from Sojourner to Curiosity**
  - Andy Mishkin, JPL Principal Engineer, MSL Mission Manager
- **Orion Human Engineering Lessons Learned: Requirements Language, HITLs, Verification Reports & More and Q&A**
  - **William Foley (JSC-SF),** Orion Human Engineering (HE) System Manager ; **Jessica Vos (JSC-XE),** Orion Vehicle Integration Office (VIO) | Crew Systems Integration Lead ; **Jason Hutt (JSC-GV),** Orion Systems Engineering & Integration Manager
- **Office of the Undersecretary of Defense Research and Engineering (OUSD(R&E)) System Engineering and Architecture (SE&A) updates on Human Systems Integration (HSI) Governance and Joint HSI Working Group Activity**
  - **Mitchell A. Woods,** Human Systems Integration (HSI) Lead Contractor support to Office of Under Secretary of Defense for Research and Engineering ; **Kenneth S. Robinson,** Human Systems Engineer, Naval Surface Warfare Center, Dahlgren Division
- **HSI Planning: Learning as We Go: CoP Internal Poll on HSI Handbook Use and Needs**
  - Lisa Rippy, Tony Thomas, Bonnie Novak (NASA HSI Handbook Team)
- **Human Systems Integration and Human Rating**
  - Jerri Stephenson, EVA and Human Surface Mobility Program (EHP) Human Systems Integration Manager
- **HSI 101 Training – Chart review for Agency level class**
  - Tony Thomas (Training Committee Co-Lead)

NASA HSI CoP Accomplishments & Future of HSI

HSI Roadmap

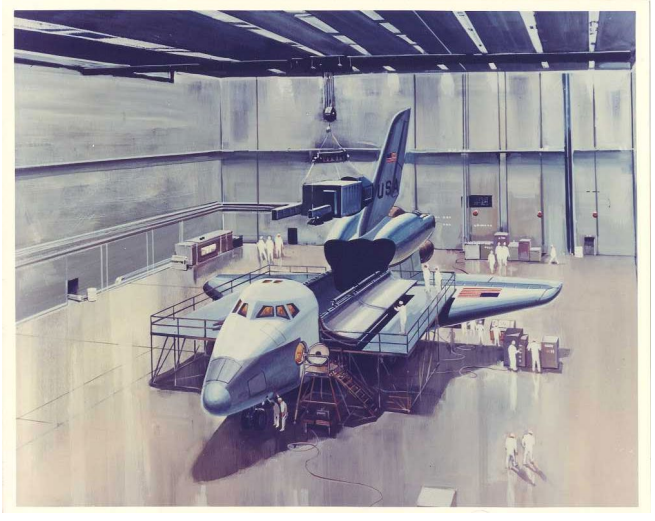
	Prior to 2020	2020 - 2022	Future Work	End State
Workforce	- HSI CoP Charter established - Established HSI in 3 Aero Projects - Partnerships established w/DoD HSI organizations - Joint HSI Working Group; Joint HSI WG Subgroups; DoD HFE Tech Advisory Group; HSI Community of Interest	- HSI Lessons learned captured as examples for HSI Handbook. - Diversified and expand CoP to be open community inclusive of all HSI domains, centers and mission directorates. - Perform basic HSI survey in SE community - Engaged all 10 centers with HSI Center Reps.	- Grow HSI Expertise across Agency - Perform HSI Gap analysis across - - Further expand HSI application to non-HEO Programs/projects - Engage Program Management and MD community - Improve quality of HSI capability - Improve awareness of HSI across Agency - Expand partnerships with other govt. orgs	- HSI is fully infused into SE (not viewed as separate process) - Human is fully accepted part of system for all Programs/projects - Decreased opportunity for human error - Increased safety, health, and performance of missions/crew at a lower full lifecycle cost.
Tools & Training	- HSI Practitioner's Guide	- HSI Handbook Baseline – Nov. 2021 - HSI Plan templates and DRD examples included in HSI Handbook - Developed HSI 101 Training. (Future work to get into SATERN training) - Held 10 informative talks from various HSI practitioners on lessons learned and different aspects of applying HSI including 1 other government agency.	- Update Handbook - Document best practices of HSI - Establish HSI lessons learned database - Develop HSI Leads Training - Identify other useful HSI Tools across domains - Update APPEL SE training to include HSI - Make Other HSI tools available across domains	- Tools become a transparent agent - HSI infused into other domain tools
Process	- HSI captured in NPR7123.1 and SE Handbook materials - Reviewed other 7120 policy series for potential HSI inclusion. - Advocated for HSI plan to be added to controlled plan list in 7120.5	- HSI inclusion in 7120.5 completed - NPR 7123.1D added HSI Plan as a requirement (on hold)	- Infuse HSI into procurement activities - Advocate for 7120.8 HSI inclusion	- HSI infused across Agency policy - HSI is fully infused into SE

CoP

Influence

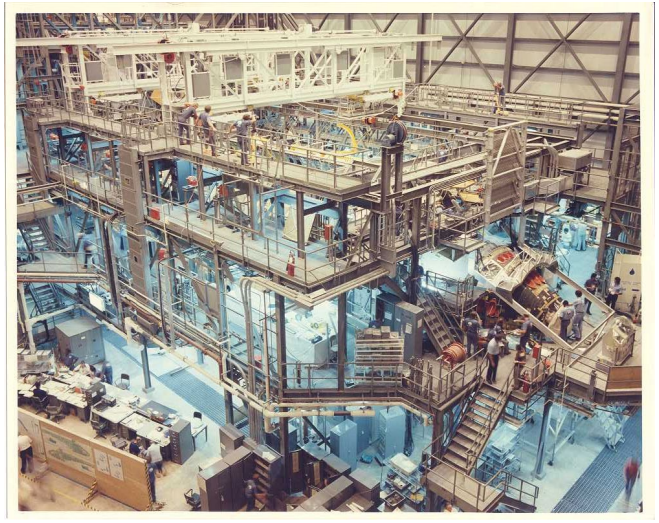
Back-up

Example: Shuttle Ground Processing Concept vs. Reality



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

NASA Example: ISS Medical Kits
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.

Example: Curiosity Mars Rover Operations - Implications of Instrument Design Choice

- ChemCam spectrometer instrument design initially included an actuated opaque cover to protect it from bring destroyed by sufficient dwell time on sun
  - Cover removed from design over concern for potential actuator failure during mission, leaving instrument unusable
- Impact ChemCam design choice
  - **All operations teams for mast-mounted instruments** (including ChemCam) **must now manually analyze all observations for ChemCam "sun-safety"**
    - **Added time to an already time-constrained operations process**
    - Sun-safety dependent on Mars time-of-day, rover attitude, mast pointing, timing of successive observations
    - Initially a manual process during Mars surface mission, until **software tools were developed to simplify assessment**

- Impact (cont.)
  - **Required development of onboard software as redundant protection for ChemCam in case of human error**
  - Resulted in
    - **Ongoing increased cost of operations**
    - **Increased risk of damage to instrument**
    - **Constraints on Mastcam and Navcam instrument observation designs**

HSI Contributions: MSL, Mars 2020, Europa Clipper

- **Major reductions in MSL daily tactical timeline duration** since landing, significantly reducing cost while increasing process sustainability.
  - Original 17 hour duration at landing
  - 7 hour duration achieved in FY19

- Current flight software lead is a HSI practitioner, actively striving to **increase spacecraft operability for a budget-constrained mission operations team**.

Mars Science Lab (MSL)

- Developing **capability for 5-hour tactical timeline** to be deployed soon after the start of the Mars surface mission
  - **Eliminates need to staff Mars time schedule while maintaining optimal mission pace**
  - Executed design simulations to prove feasibility
  - **Developing enabling tools and processes**

Mars 2020

- HSI personnel embedded in Europa Clipper Mission Operations System (MOS) and Ground Data System (GDS) development teams, responsible for multiple mission priorities:
  - Ensure coordination of mission operations concept development between mission system and science teams
  - **Joint development with science team of science user-centered mission planning process**
  - **Common model interface architecture design**, resulting in GDS tool design and adaptation of existing tools
  - **Design and validation of operations processes around constraint-based planning and downlink prioritization** within the unique limitations of the mission
  - Periodic design simulations to validate processes before final acceptance

Europa Clipper