Human Systems Integration

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Human systems integration (HSI) is "the management and technical discipline of planning, enabling, coordinating, and optimizing all human-related considerations during system design, development, test, production, use and disposal of systems, subsystems, equipment and facilities." (SAE 2019).

Though used by industries around the world, HSI was initiated by the U.S. Department of Defense (DoD) as part of the "total system approach" to acquisition. The goal of HSI is to "optimize total system performance (hardware, software, and human), operational effectiveness, and suitability, survivability, safety, and affordability." (DoD 2003.) This article itself focuses on HSI within the DoD, although much of it is applicable to other government and commercial organizations worldwide.

HSI activities must be initiated "early in system development (during stakeholder requirements generation) and continuously through the development process to realize the greatest benefit to the final system solution and substantial life cycle cost savings." (INCOSE 2015).

HSI generally incorporates the following seven domains as integration considerations (although some organizations may use a slightly different set): manpower, personnel, training, human factors engineering, safety and occupational health, force protection and survivability, and habitability.

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Overview

Historically, insufficient systems engineering resources were dedicated to ensuring proper integration of humans with the rest of the system. Most projects were technology-centered with human considerations being addressed through training. Technological systems were hard to use and maintain resulting in large manpower and training costs, reduced system performance, and increased risk of catastrophic loss, among other impacts.

The U.S. Army was among the first to address this with the Manpower and Personnel Integration (MANPRINT) program in 1986. MANPRINT emphasized the consideration of the HSI domains throughout the system acquisition as a standard part of the systems engineering effort. The approach has since been adopted by the broader DoD, by other militaries, and by civilian

government agencies around the world. (Booher 2003). Some organizations, particularly the U.K. Ministry of Defence, use the term Human Factors Integration (HFI).

HSI applies systems engineering processes, tools, and techniques to ensure that human considerations are given proper weight in all system development activities. HSI should not be confused with Human Factors Engineering (HFE); HFE is a domain of HSI focusing on designing human interfaces. HSI is about mutual integration of technology, organizations, and people.

System Description

HSI is more than human factors, human-computer interaction, or systems engineering. It is a technical and managerial set of processes that involves the consideration and integration of multiple domains. In addition, HSI involves complexity analysis and organization design and management. Various organizations represent the HSI domains differently as the number and names of the domains are aligned with existing organizational structures. Booher (2003) first presented the original seven US Army domains as manpower, personnel, training, human factors engineering, soldier survivability, system safety and health hazards. Other countries may have a different number of domains with slightly different names, however, all the technical work of the domains is present. For example, the UK Defence Standard (00-251) includes seven similar domains: manpower, personnel, health hazards, training, human factors engineering, social/ organizational and system safety. The seven domains used across the DoD Instruction (DoD 2017) that tells how to operate the DoD Acquisition System are as follows:

1. **Manpower** Determining the most efficient and cost-effective mix of manpower and contract support necessary to operate, maintain, provide training and support the system. Manpower describes the number and mix of personnel required to carry out a task, multiple tasks, or mission in order to operate, maintain, support, and provide training for a system. Manpower factors are those variables that define manpower requirements. These variables include job tasks, operation/maintenance rates, associated workload, and operational conditions (e.g., risk of operator injury) (DAU 2010).
2. **Personnel:** Determining and selecting the

appropriate cognitive, physical, and social capabilities required to train, operate, maintain, and sustain systems based on available personnel inventory or assigned to the mission. Personnel factors are those human aptitudes (i.e., cognitive, physical, and sensory capabilities), knowledge, skills, abilities, and experience levels that are needed to properly perform job tasks. Personnel factors are used to develop occupational specialties for system operators, maintainers, trainers, and support personnel (DAU 2010). The selection and assignment of personnel is critical to the success of a system, as determined by the needs set up by various work-related requirements.

3. **Training:** Developing efficient and cost-effective options that enhance user capabilities and maintain skill proficiencies for individual, collective, and joint training of operators and maintainers. Training is the learning process by which personnel individually or collectively acquire or enhance pre-determined job-relevant knowledge, skills, and abilities by developing their cognitive, physical, sensory, and team dynamic abilities. The "training/instructional system" integrates training concepts and strategies, as well as elements of logistic support to satisfy personnel performance levels required to operate, maintain, and support the systems. It includes the "tools" used to provide learning experiences, such as computer-based interactive courseware, simulators, actual equipment (including embedded training capabilities on actual equipment), job performance aids, and Interactive Electronic Technical Manuals (DAU 2010).
4. **Human Factors Engineering:** The integration of human characteristics into system definition, design, development, and evaluation to optimize human-system performance under operational conditions. Human factors engineering (HFE) is primarily concerned with designing human-machine interfaces consistent with the physical, cognitive, and sensory abilities of the user population (DAU 2010). It focuses on ensuring that the system design is compatible with the human user. HFE considers required human tasks, and the sensory, perceptual, mental, and physical attributes of the user personnel who will operate, control, maintain, and support the equipment, system, or facility. The objective of HFE is to optimize human-

system performance within the desired levels of life-cycle costs. HFE domain considerations span a wide range and include design and layout of working areas, user-equipment interfaces, use of automation and decision aids, and normal, non-normal, and emergency conditions.

5. **Safety & Occupational Health:** Consider environmental, safety and occupational health in determining system design characteristics to enhance job performance and minimize risks of illness, disability, injury and death to operators and maintainers. Safety considers the design features and operating characteristics of a system that serve to minimize the potential for human or machine errors or failure that cause injurious accidents (DAU 2010). Safety also encompasses the administrative procedures and controls associated with the operations, maintenance, and storage of a system. Occupational health factors are those system design features that serve to minimize the risk of injury, acute or chronic illness, or disability, and/or reduce job performance of personnel who operate, maintain, or support the system. Prevalent issues include noise, chemical safety, atmospheric hazards (including those associated with confined space entry and oxygen deficiency), vibration, ionizing and non-ionizing radiation, and human factors issues that can create chronic disease and discomfort such as repetitive motion diseases. Many occupational health problems, particularly noise and chemical management, overlap with environmental impacts. Human factors stress that creating a risk of chronic disease and discomfort overlaps with occupational health considerations (DAU 2010).
6. **Force Protection & Survivability:** Impact system design (e.g., egress, survivability) to protect individuals and units from direct threat events and accidents, including chemical, biological, and nuclear threats. Force Protection and Survivability is the HSI domain that facilitates system operation and personnel safety during and after exposure to hostile situations or environments. Force protection refers to all preventive measures taken to mitigate hostile actions against personnel (to include family members), resources, facilities, and critical information. Survivability denotes the capability of the

system and/or personnel manning the system to avoid or withstand manmade hostile environments without suffering an abortive impairment of his/her ability to accomplish its designated mission. Survivability factors consist of those system design features that reduce the risk of fratricide, detection, and the probability of being attacked, and that enable personnel to withstand man-made hostile environments without aborting the mission or objective, or suffering acute chronic illness, disability, or death. Survivability attributes are those that contribute to the survivability of manned systems (DAU 2010).

7. **Habitability:** Establishing and enforcing requirements for individual and unit physical environments, personnel services, and living conditions, to prevent or mitigate risk conditions that adversely impact performance, quality of life and morale, or degrade recruitment or retention. Habitability factors are those living and working conditions that are necessary to sustain the morale, safety, health, and comfort of the user population. They directly contribute to personnel effectiveness and mission accomplishment and often preclude recruitment and retention problems. Examples include lighting, space, ventilation, and sanitation; noise and temperature control (i.e., heating and air conditioning); religious, medical, and food services availability; and berthing, bathing, and personal hygiene. Habitability consists of those characteristics of systems, facilities (temporary and permanent), and services necessary to satisfy personnel needs. Habitability factors are those living and working conditions that result in levels of personnel morale, safety, health, and comfort adequate to sustain maximum personnel effectiveness, support mission performance, and avoid personnel retention problems (DAU 2010).

Discipline Management

In a contractor project organization, the human systems integrator is typically a member of the senior engineering staff reporting to either the systems engineering lead or chief engineer.

HSI activities are documented in the Systems

Engineering Management Plan (SEMP). Larger programs may have a stand-alone HSI Plan (HSIP) compatible with and referenced by the SEMP. HSI activities are tailored to the needs of the project and the project life cycle (NASA 2016).

Most projects implement a Joint HSI Working Group between the customer and contractor. This enables sharing of priorities, knowledge, and effort to allow each group to achieve their objectives.

Discipline Relationships

Interactions

Interactions include:

- SE: HSI is an integral part of the systems engineering effort and the integrator participates in all relevant systems engineering activities during the whole life cycle of the system being considered.
- HSI domain experts: Domain experts collaborate with the human systems integrator to achieve HSI objectives, though this may or may not be a direct reporting relationship.
- The contractor and customer may each have a human systems integrator and various domain experts; each role should collaborate with their counterparts to the appropriate extent.
- HSI domain experts may participate in integrated product teams (IPTs)/design teams as full participants or consultants as appropriate for the needs of the project.
- HSI shares many concerns with Reliability, Availability, and Maintainability (RAM). The integrator and/or domain experts may collaborate with RAM specialists as appropriate.
- The integrator and/or domain experts should work with the Test & Evaluation team to ensure that HSI is represented in test and evaluation events.
- HSI shares many concerns with logistics and supportability, the integrator and/or domain experts may collaborate with this team as appropriate.

Dependencies

HSI depends on sufficient scope of work and authorization from the project. Proper planning and leadership buy-in is a key enabler.

Discipline Standards

Note: These are standards relevant to the practice of HSI specifically and not each of the HSI domains, which have their own standards and practices.

- National Aeronautics and Space Administration (NASA). 2015. Human Systems Integration Practitioner's Guide. NASA/SP-2015-3709. Houston: Johnson Space Center.
- SAE International. 2019. Standard Practice for Human Systems Integration. SAE6906. Warrendale, PA: SAE International.
- U.K. Ministry of Defence. 2016. Defence Standard 00-251: Human Factors Integration for Defence Systems. Glasglow: Defence Equipment and Support.
- U.S. Army. 2015. Regulation 602-2: Human Systems Integration in the System Acquisition Process. Washington: Headquarters, Department of the Army.
- U.S. Department of Defense. 2011. Data Item Description: Human Systems Integration Program Plan. DI-HFAC-81743A.
- U.S. Navy. 2017. Opnav Instruction 5310.23A: Navy Personnel Human Systems Integration. Washington: Office of the Chief of Naval Operations: Department of the Navy.

Personnel Considerations

HSI is conducted by a human systems integrator. The integrator is part of the systems engineering team responsible for conducting systems engineering related to human and organizational considerations and for coordinating the work of the HSI domain experts.

HSI uses the same techniques and approaches as systems engineering with additional consideration for non-materiel aspects of the system. Therefore, the integrator must be well-versed in the SE process and have a working understanding of each of the domains. The integrator does not need to be an expert in any of

the domains.

The human systems integrator's responsibilities include:

- providing inputs to the SEMP and/or creating an HSI Plan (HSIP) compatible with the SEMP and the project life cycle (NASA Systems Engineering Handbook 2016)
- tailoring the scope of HSI efforts to the needs of the project and system life cycle
- ensuring HSI domains are given appropriate consideration across all programmatic and engineering activities
- assisting domain personnel in planning domain activities
- facilitating execution of domain tasks and collaboration among domains
- making tradeoffs among domains to optimize the attainment of HSI goals
- optimizing the impact of domains on the acquisition program from the perspectives of performance, sustainability, and cost
- integrating the results of domain activities and representing them to the rest of the acquisition program from a total HSI perspective
- facilitating interactions among domains within the scope of HSI, and between HSI and the rest of the program
- tracking, statusing, and assessing HSI risks, issues and opportunities that have surfaced during the execution of the program

Metrics

Human-System Measures of Effectiveness

A measure of effectiveness (MOE) is a metric corresponding to the accomplishment of the mission objective. MOEs measure system performance in a representative mission context, including with representative users. Effectiveness is typically achieved through a combination of hardware, software, and human components, thus there are not typically HSI-specific MOEs.

MOEs may be decomposed into measures of performance (MOP) and measures of suitability (MOS).

There may be HSI-specific MOPs and MOSs. For example, an MOE for an air defense radar might be positive detection probability, with an MOP for the radar's effective resolution and an MOP for the operator's ability to identify the target. It is the human system integrator's responsibility to ensure that relevant MOPs and MOSs are identified and incorporated into modeling, simulation, test, and evaluation efforts. The integrator and domain experts may contribute to these efforts as appropriate.

Models

HSI Process Models

HSI shares common systems engineering models with general systems engineering; e.g. the SE Vee process model. Additionally, a number of HSI-specific models and processes exist. A particularly good resource is "A User-Centered Systems Engineering Framework" by Ehrhart and Sage (in Booher 2003).

Human Performance and Domain Models

A variety of human performance models exist for cognition, behavior, anthropometry, strength, fatigue, attention, situation awareness, etc. Additionally, a variety of models exist for each HSI domain. The integrator should have a good understanding of the types of models available and the appropriate applications. In a project utilizing model-based systems engineering, the system model should include humans. The integrator should ensure sufficient fidelity to meet the needs of the project. Human-in-the-loop simulations should be encouraged during the design process as during the whole life cycle of a product.

Tools

HSI shares common tools with systems engineering. A sample of HSI-specific tools include:

- Command Control and Communications - Techniques for Reliable Assessment of Concept Execution (C3TRACE) developed by U.S. Army Research Labs.
- Comprehensive Human Integration Evaluation Framework (CHIEF) developed by U.S. Navy.
- Human Analysis and Requirements Planning System

(HARPS) developed by U.S. Navy Space and Naval Warfare Systems Command.
- Human Systems Integration Framework (HSIF) developed by U.S. Air Force. (USAF 2009)
- Improved Performance and Research Integration Tool (IMPRINT) developed by U.S. Army Research Labs.

Additionally, each HSI domain has specific tools and approaches for their unique efforts and considerations.

Practical Considerations

Pitfalls

Many organizations assign a human factors engineer to the human systems integrator role. This can be a mistake if the individual is not well versed in the SE process. Relegating HSI to a "specialty engineering" team deprives the integrator of sufficient scope and authority to accomplish their mission.

Proven Practices

Ensure the human systems integrator is a knowledgeable systems engineer with the respect of the other systems engineers and with a good understanding of each of the HSI domains. A human systems integrator should be involved in program planning activities to ensure sufficient budget and schedule. They should be involved in technical planning activities to create sufficient scope in the SEMP/HISPP, identify HSI-related risks and opportunities, recommend HSI trade studies, etc. There is significant overlap and trade space among the HSI domains, therefore the domain experts, led by the integrator, should collaborate throughout the project to optimize the impact of HSI.

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None.

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