Human Systems Integration

Definition

Human Systems Integration (HSI) is an approach that integrates technology, organizations, and people effectively.

HSI is an essential, transdisciplinary, sociotechnical, and management approach of SE to ensure that the system's technical, organizational, and human elements are appropriately addressed across the whole system life cycle, service, or enterprise system. HSI considers systems in their operational context and the necessary interactions between and among their human and technological elements to make them work in harmony and cost-effectively, from concept to retirement.

Key Concepts

Human

The "human" in HSI includes all individuals and groups interacting within the SoI. Within HSI, these are typically referred to as "stakeholders." Stakeholders can include system acquirers, owners, users, operators, maintainers, trainers, support personnel, and the public. While most people who interact within the SoI will be cooperative or have a vested interest in its performance, consideration may also need to be given to non-cooperative people or those with malign intent such as competitors, adversaries, criminals (physical and cyber), and those seeking to use the system outside of its design intent. Life, human, and social sciences have different representations of the human element and can all bring different perspectives to HSI activities.

Systems

HSI adopts a sociotechnical system perspective that considers a system as a representation of natural and artificial elements that are organizations of humans and machines (where machines include both hardware and software). Therefore, HSI considers that all systems include both humans and machines, and to optimize the system, all of these elements must be considered within SE activities.

Integration

HSI considers integration from two key viewpoints. The first is the effective integration of the human and technological elements in a system. The second is the efficient integration of the different perspectives of both human and machine elements within the system. An example of these different HSI perspectives can be seen in Figure 3.5. The specific perspectives relevant to a project will vary depending on the nature of the system and the organization's activities.

All systems involve or affect people and exist within a wider sociotechnical and organizational context. Therefore, HSI is an essential enabler of SE practice. The sociotechnical approach provided by HSI supports analysis, design, and evaluation activities in holistically understanding and effectively integrating a system's technological, organizational (including processes), and human elements. As shown in Figure 3.5, HSI emerges from the overlapping of three main circles: (1) technology, organization, and people (the TOP Model) within an environment at the heart; (2) HSI perspectives; and (3) contributing disciplines associated with the operational domain shown in the periphery. It is particularly important that systems are designed to meet human capabilities, limitations, and goals.

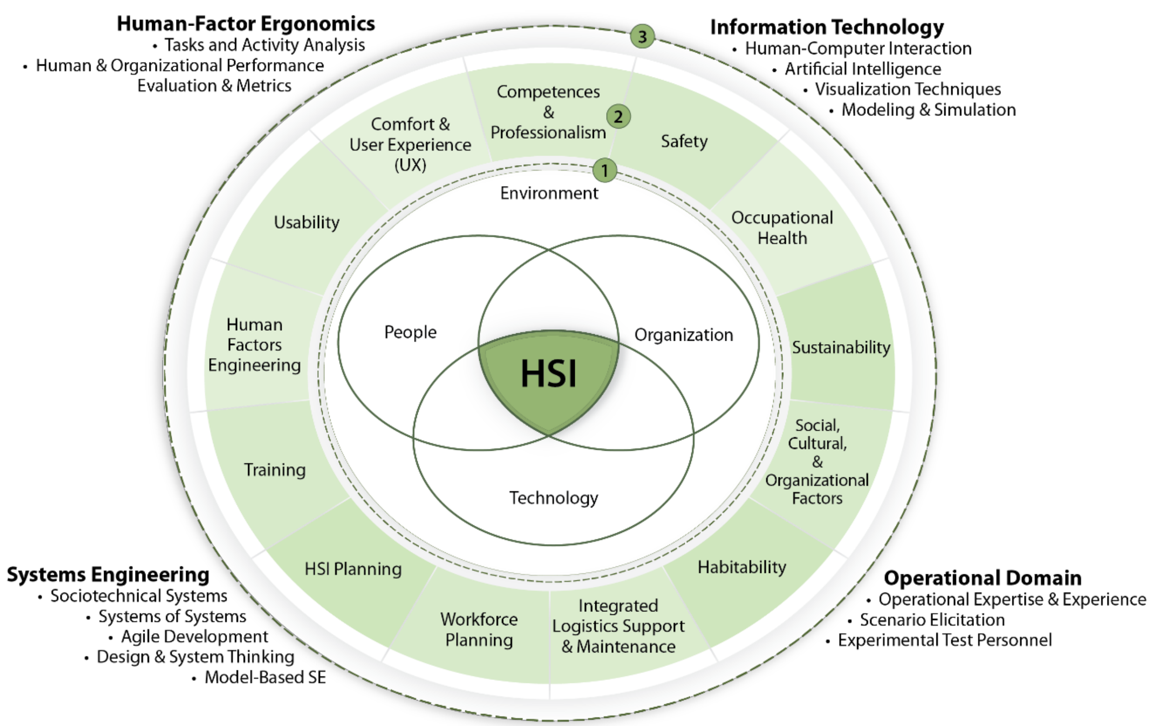

Figure 3.5 HSI technology, organization, and people within an environment.
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Elaboration

Purpose and Value of HSI

HSI aims to optimize total system performance and stakeholder satisfaction through the mutual integration of technology, organizations (including processes), people, and environment.

The benefits HSI can realize vary from domain to domain, depending on their priorities and purpose (e.g., safety, cost, efficiency, performance, acceptability) and the nature of the system. They can be broken down into the following areas:

- *holistic optimization of system performance and efficiency*: participatory design and human-in-the-loop (HITL) activities;
- *improved safety*: hazard, risk, performance limitations, and emergent properties analysis;
- *reduced development costs*: consider the TOP Model;
- *reduced system LCC costs*: HSI from the beginning of the SE life cycle;
- *improved sales:* resulting from product or service usability;
- *user experience (UX) and desirability:* focus on Human-Centered Design (HCD) and user needs;
- *improved adoption of new systems by the workforce or user groups:* considering sociotechnical factors;
- *HSI value to a project*: from intuition to expertise in HSI,

Scope and Breadth of HSI

HSI is based on the convergence of four key communities of practice (third circle in Figure 3.5):

- *human factors and ergonomics (HF/E)* that provides human-centered and organization-centered analysis, performance evaluation techniques, and metrics (Boehm-Davis, et al., 2015);
- *information technology (IT)* that includes human-computer interaction, artificial intelligence, visualization techniques, and modeling and simulation;
- *systems engineering* that includes socio-technical systems, systems of systems (see Section 4.3.6), agile development (see Section 4.2.2), design and system thinking (see Sections 3.2.7 and 1.5), and model-based SE (MBSE) (see Section 4.2.1); and
- *the operational domain* that includes operational expertise and experience, scenario elicitation, and experimental test personnel (see Section 4.4).

These communities enable support of HSI through HCD as a major process that involves the development and use of domain ontology, prototypes and digital modeling, scenario-based design, modeling and HITL activities (simulations and physical tests), formative evaluations, agile design, and development, as well as human performance and organizational metrics (e.g., maturity and flexibility) (Boy, 2013) (Boy, 2020). HCD validation both requires certification approval and contributes to certification rules evolution.

HSI considers systems complexity analysis as a baseline. It seeks simplification (where possible) and familiarity with complex systems (where necessary). HITL activities enable the discovery and elicitation of complex systems' emergent behaviors, properties, functions, and structures, which are incrementally integrated into the SoI through its whole life cycle. HITL activities provide SE and HCD teams with improved understanding of the SoI early in the life cycle, contributing to design flexibility and better resource management. HSI is a foundational enabler for industrial endeavors, such as Industry 4.0, where digital engineering, enabling virtual HCD, requires increased physical and cognitive tangibility testing across the life cycle of a system (see Section 5.4). Case 5 (Artificial Intelligence in Systems Engineering - Autonomous Vehicles) from Section 6.5 illustrates the importance of all these aspects.

HSI can be considered as both an *enabling process*, associating HCD and SE during the life cycle of a system, and a *product* resulting from this process. HSI is the result of this HCD-based convergence, which requires optimizing the TOP Model. User eXperience (UX) and User Interface (UI) development are integral parts of the HSI process from the early stages and throughout the system life cycle. HSI processes are iterative and supported by two main types of assets, methods, and tools: expertise elicitation and creativity. The former enables effective elicitation from subject matter experts through knowledge and know-how, supporting design teams during system formative evaluations, agile development, and certification. The latter enables out-of-the-box projections that are validated using prototyping and HITL activities.

HSI Perspectives

HSI encompasses several important perspectives displayed in Figure 3.5 (second circle) and described in more detail in Table 3.2.

Table 3.2 HSI perspective descriptions. INCOSE SEH original table created by Boy.

Human Factors Engineering (*HFE*) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and other methods to design in order to optimize human well-being and overall system performance.
Social, Cultural, and Organizational Factors consider the organizational aspects of socio-technical systems and includes the organizations who will be using and supporting the operational system, as well as the organizations who are involved throughout the entire life cycle of the system.
HSI Planning addresses the implementation of HSI through the SE process to ensure the human element is effectively integrated with the system. HSI strategies and priorities need to be set up-front, can be formalized in the

HSI Plan, and potentially adjusted during the life cycle, upon mission definition, and carried throughout the allocation of resources and project personnel.
Integrated Logistics Support (ILS) & Maintenance covers human performance during the whole life cycle of a system based on an ILS plan supported by an HSI plan. ILS includes training, operations, maintenance, potential redesign, and dismantling.
Workforce Planning addresses the number and type of personnel and the various occupational specialties required and potentially available to develop, train, operate, maintain, and support the system.
Competences and Professionalism consider the type of knowledge, skills, experience levels, and aptitudes (cognitive, physical, and sensory) required to operate, maintain, and support a critical system and the means to provide such people (through selection, recruitment, training, etc.).
Training encompasses designing to account for ease and reduction of operation time needed to provide training through trade studies evaluated to assess their impact on training, as well as the instructions and resources required to provide personnel with requisite competence, knowledge, skills, and attitudes to properly operate, maintain, and support systems.
Safety promotes system characteristics and procedures to minimize the risk of accidents or mishaps that cause death or injury to operators, maintainers, support personnel, or others who could come into intentional or unintentional contact with the system; threaten systems operations; or cause cascading failures in other systems. It includes survivability.
Occupational Health promotes system design features and procedures that serve to minimize physiological mental and social health hazards which might result in injury, acute or chronic illness, and disability; and to enhance job performance and wellbeing of personnel who operate, maintain, or support the system.
Sustainability covers the environmental considerations that can affect operations and particularly human performance and considers wider ranging concerns and long-term goals of how the humans within the system can affect the environment, society, and economy without compromising future generations' needs.
Habitability involves characteristics of system living and working conditions.
Usability involves objective evaluation methods to address aspects such as efficiency, conformity to human expectations, tolerance/resistance toward human errors, and learnability to improve the degree to which humans can reach their objectives when interacting with a system.
Comfort and UX are personal internal human aspects such as joy, guilt, opinions and unconscious aspects which are to be considered, not only regarding the primary users of the final product, but in regard to all humans involved in the systems engineering process.

A wide variety of HSI methods, models, knowledge, and approaches can support decisions made across the whole system life cycle. This can include support to requirements analysis, trade studies, life cost-benefit analysis, options or tender down selection, risk management, safety case development, design decisions, acceptance testing, and workforce planning. Human-related trade studies are critical to determining the holistic operational concept (OpsCon) and informing the design team regarding effectivity, efficiency, suitability, usability, safety, and affordability. See the INCOSE HSI Primer (2023) for more details.