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Human Systems Integration
A Contemporary Discipline

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The engineering community often asks for clarification on what Human Systems Integration (HSI) entails. HSI often suffers from an identity crisis; common opinions heard are that it is synonymous with human factors and ergonomics, a matter of designing user interfaces, integration of the human with computer systems, or a checklist of human-centered evaluations once an engineering system is partially or fully developed, and so on. In truth, HSI includes these areas or activities, but the scope is far wider. Despite having its origins four decades ago, these misconceptions around HSI continue to persist

What is HSI today and what should we be doing? This article addresses these questions and emphasizes the evolution of HSI, why it is crucial to systems engineering and how it is becoming a contemporary discipline.

The latest of *INCOSE HSI Working Group* definition reads as follows:

> Human Systems Integration (HSI) is a transdisciplinary sociotechnical and management approach of systems engineering used to ensure that a system's technical, organizational, and human elements are appropriately addressed across the whole system lifecycle, service, or enterprise system. HSI considers systems in their operational context together with the necessary interactions between and among their human and technological elements to make them work in harmony and cost effectively, from the early design to disposal.

Since the inception of HSI in the 1980s (Booher, 2003), the essence of the definition has not changed significantly – put simply HSI ensures that the human concerns are voiced throughout the systems lifecycle and explicitly part of the planned Systems Engineering efforts. So why do the misconceptions persist and where do they stem from? To understand these questions, it is important to understand the context of HSI's origins and how it has evolved from and alongside more commonly understood disciplines.

1. From User Interfaces to Human-Centered Design

For a long time, engineering was dominated by mechanical engineering, where mathematics, physics and other "hardcore" technical disciplines were the main support for correctly making engineering systems. Human Factors and Ergonomics (HF&E) developed after World War 2

originally to adapt people to machines, even if it was often said the opposite. Dominant issues were physical, and HF&E was mostly based on physiology and biomechanics. Practitioners developed methods and tools to improve human-machine adaptation in a physical way.

Circa 1980, human-centered engineering design approaches started to appear, especially with the development of microcomputers and universal dissemination of office automation. Human-Computer Interaction (HCI) became a major focus for the development of software-based user interfaces. Interaction design then became a major focus. Computer graphics developed and progressively supported HCI, and more specifically user-friendly human-machine interfaces. However, user interfaces still were considered as add-on components of machines, typically developed when the core machine technology was fully developed.

Human-Centered Design (HCD) was born within the HCI community (Norman, 1990; Boy, 2013). This was because interaction design is naturally participative and digital media enabled the consideration of human factors in computing systems design seriously. However, since its inception during the 1980s, the HCI community mainly focused on personal computing and consumer electronics. The massive introduction of software-based automation in aircraft cockpits, for example, incrementally led to consider a more systemic approach to HCD. We started to talk about onboard embedded systems and today cyber-physical systems. HCI in the cockpit started to reveal new research concerns, such as cognitive engineering, advanced interaction media for complex life-critical systems control and management, complexity analysis, organization design and management, and finally, virtual modeling, prototyping and simulation. We needed to wait until the beginning of the 21st century to be able to have real HCD approaches, where machines and stakeholders could be considered from the beginning of the design process throughout the entire life cycle of a technological system. Why? The reason is simple: modeling and simulation started to realistically support user experience from the beginning of the design process. It became possible to run human-in-the-loop simulations at design time, and incrementally use experience feedback to improve engineering design.

Concretely, the *HCI-Aero Conference Series*, born within the HCI community, led to the inauguration of the INCOSE HSI Biennial Conference in 2019. Of course, virtual HCD is not exclusive to the aeronautics domain only, but in a large variety of domains where life criticality was at stake. HCD nurtured from human-in-the-loop simulation became possible thanks to the development of virtual prototypes and formative evaluation techniques whose evolution also became compatible with agile approaches. For these reasons HCD started to expand into the system engineering world. HCD is no longer a matter of user interface design that has the goal to adapt people to machines, but to enable the co-adaptation of people and machines since the very beginning of design to the dismantling phase of complex systems. M&S (Modeling & Simulation) enables design flexibility, improves resource commitment management, and capitalizes on system knowledge. Today's digital twin approaches are the

result of this evolution. Indeed, developing the design process and its solution(s) through shifting from document- to model-centric efforts lead to model based HSI (Boy, 2020).

2. The systemic evolution of Human-Centered Design toward HSI

INCOSE was formed in the 1990s and framed systems engineering as heavily technology-centered. Until recently, systems engineers were counting on HF&E and HCI specialists for the adaptation of people to the machines they developed. The user interface was the solution, based on usability engineering. At the same time, our world became more digital and complex in the interconnectivity sense. We now needed to deal with new types of complexity that required new tools and methods.

During the past decade or so, HSI has evolved and cross-fertilized from HCD to Systems Engineering (SE), subsequently being extended as the combination of HCD and SE (Boy & Narkevicius, 2013). HSI became a crucial necessity because we started to understand that the co-adaptation of people and machines is a deeper enterprise that should be considered during the whole life cycle of a sociotechnical system. Today, we are no longer focusing solely on a user facing a machine through a user interface, we need to investigate an entire organization of people and smarter systems functioning cooperatively. We are no longer interested in a single agent approach, but in understanding how several human and machine agents can work together and how such agents are defined and organized.

In addition to physical and cognitive factors, the social factor of HSI became essential. Engineering design is not only a matter of technology and people using a technology in isolation, but a matter of organization design and management. This is the reason why HCD could not stay based on single agent premises, but on multi-agent representations. The very notion of a *system* had to be updated, a system is not only a concept representing artificial things. Systems can represent people, products, services, information, processes, and natural elements. Furthermore, the multi-agent socio-cognitive shift is now consistent with the notion of system of systems.

3. INCOSE HSI Working Group Mission

The INCOSE HSI Working Group's current mission is to share experiences, learnings and understanding around the emergence of HSI as a contemporary discipline. As with all emerging disciplines, we seek to formalize and disseminate this new knowledge for both existing professionals and students. The HSI WG's role is also to offer a forum for practitioners and researchers who need to exchange ideas and current practice in the field of HSI. Volunteer WG members with different perspectives and learnings are needed to ensure the progression of the discipline. We are organizing regular events, such as conferences and workshops, as well as monthly meetings. During the COVID period, these events and meetings were, and still are, virtual. We can't wait to organize them in person soon hopefully. We are

also producing materials for the SE and HSI community. Figure provides a snapshot of our current activities.

Over the last five years the INCOSE HSI WG hasn't stopped growing and continues to produce materials that support its definition and development of associated methods and tools. As an example, the *HSI WG Workshop* organized in October 2020 gathered 350 participants from 24 countries. We devoted a great effort to the write up of the HSI chapter for the fifth edition of INCOSE SE Handbook, together with a contemporary HSI Primer. The first INCOSE HSI conference was held in September 2019 in Biarritz, France, and the second as a virtual event in November 2021. The HSI conferences are organized every two years, alternately with the HSI workshops.

Figure1. Current HSI WG Activities.

4. References

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