Human Systems Integration, it's time to take centre stage

- As humans and technology converge, opportunities and concerns escalate.
- Human Systems Integration, or HSI, is a transdisciplinary field making sense of the resulting combined complexity.
- Dr Guy André Boy of Paris Saclay University (CentraleSupélec) and ESTIA Institute of Technology, France, is a leading figure in HSI.
- HSI has guided the design of highly advanced complex, life-critical, and increasingly autonomous systems in sectors such as aerospace and defence.
- But as we enter Society 5.0, HSI is finding its place in shaping our everyday lives.

There is an old engineering design joke, probably more a wry observation, that the most dangerous component to a motor vehicle is the nut holding the steering wheel. On its own, without humans, a motor vehicle is an inert, albeit highly complex, technological system. It takes people, also a highly complex sociotechnical system, to activate and apply its purpose. However, that purpose does not necessarily need to be part of its original design – a car can transport its occupants safely, efficiently, and comfortably, but it can also kill. As humans and technology converge, making sense of the resulting combined complexity is the focus of an interdisciplinary field called human systems integration, or HSI.

For decades, it has guided the deisgn of highly advanced complex and life-critical systems in sectors such as aerospace and defence. However, as we enter Society 5.0, HSI is finding its place in shaping our everyday lives, considering new social and organisational issues. One scientist and engineer is at the forefront of the field, encouraging its adaptation to its evolved purpose.

Within the field of human systems integration, the work of Dr Guy André Boy stands out. Boy is FlexTech Chair Professor at Paris Saclay University (CentraleSupélec) and ESTIA Institute of Technology and a fellow of the International Council on Systems Engineering (INCOSE). The former IPA Chief Scientist for Human–Centered Design at NASA Kennedy Space Center is a computer scientist, aerospace and control engineer, and cognitive scientist. He is well known for his research and expertise in artificial intelligence (AI), cognitive engineering, human–computer interaction, human-centered design, and socio-ergonomics. There are few areas within HSI where Boy has not made his mark and helped guide its development. To some degree, it could be argued that HSI has been waiting in the wings and that now is its time to step into the spotlight. In that case, Guy will be part of the team taking centre stage.

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Society 5.0 – the future

Technology has become increasingly digital and vital in our lives. It is also central to the concept of Society 5.0. The term builds upon previous industrial and societal stages – hunting (Industry 1.0), agriculture (Industry 2.0), industrialisation (Industry 3.0), and the information age (Industry 4.0). The switch from 'Industry' to 'Society 5.0' is a result of HSI – and imagined as a highly connected, knowledge-based society that leverages emerging technologies to tackle social challenges and global issues. It is not that far off; indeed, we could argue that we have one foot in the door.

For Boy and other HSI specialists, the deeper convergence of technological and human systems that Society 5.0 demands invite opportunity and concern. Seamlessly integrating emerging technologies such as AI, biotechnology, robotics, big data, virtual reality, and the Internet of Things (IoT) will provide an evolutionary leap in technological advancement. Directing those towards significant challenges, such as curing cancer, responding more effectively to crises, and helping secure environmental stability are central to the Society 5.0 ideal. Nevertheless, technology is just one component of HSI – a car is not just a car when a human is at the controls in a populated environment.

In their shaping HSI, Boy and his colleagues at FlexTech and INCOSE HSI working group go beyond the remainder of renowned psychologist James Reason, an influential figure in human error and safety: 'Fallibility is part of the human condition.' Indeed, this is only one part of the overall HSI problem, which is to discover and learn from emergent behaviours and properties, whether positive (good practice) or negative (failures), as early as possible during design as well as the whole life cycle of sociotechnical systems, using digital human-in-the-loop simulations, to make these systems acceptable. Departing from the conventional human-error-based approach, Boy emphasises the maturity, flexibility, tangibility, responsibility, and sustainability of sociotechnical systems, specifically regarding authority sharing between humans and interactive machines.

Such realities are why the insights of specialists within the transdisciplinary field of HSI are critical. They draw on decades of research and experience in not only systems engineering, human–computer interaction, operations research, ergonomics, safety engineering, data analytics, information technology and computer science but also cognitive science, sociology, industrial, and organisational psychology, and human biology, to mention just a few. They

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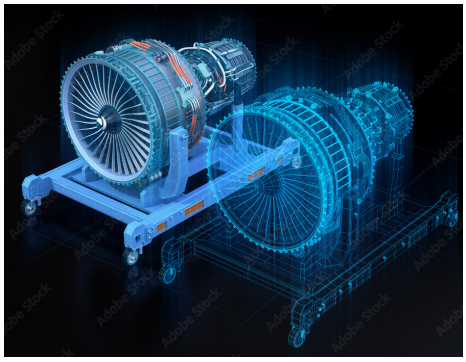
HSI in our growing digital engineering world requires the development of physical and figurative tangibility.



A system is a representation of artificial and living entities.

are therefore well-schooled in the opportunities for both the advancement and misfortune that come with teaming technological and human systems. Consider the early outcomes of human-AI teaming: it may have designed AlphaGO, but it also gave us images of Pope Francis looking dapper in a white puffer jacket.

Human Systems Integration is about life-centered design.

The quest for epistemological foundations

As Boy points out, as machines become more intelligent and interconnected, human–machine teaming requires more profound studies of operational performance, trust, and collaboration between humans and machines. HSI is also not only interdisciplinary but also growing exponentially. With every emerging technology comes not only a raft of new terms but the need to examine the systemic foundations for human interaction with it. He is therefore pushing for developing deeper, epistemological foundations for HSI. To this end, he calls for developing a consistent terminology and a proper ontology' for this nascent, ever-developing field.

For those new to the term, 'human systems integration' may suggest user interfaces, operational procedures, and human-centred design. For Boy, it is a much deeper endeavour rooted in the science of

> **Human Systems Integration tries to articulate technology, organisations, and people.**

artefact, where technology, organisations, and people – often referred to as the triptych TOP – must be integrated. It is about dynamically building machines that meet human and organisational requirements and gradually refining needed emergent skills and appropriate organisational structures that are agile and adaptive. Because without that, we are just the nut holding the steering wheel.

Personal response

What is the one insight from HSI that will serve as a suitable maxim for Society 5.0?

HSI supports social, sustainable, and living factors involved in the design, development, and operations of our sociotechnical Society 5.0. In Industry 4.0, operational procedures and user interfaces have been developed, mostly rigidifying human activity around technology. From the perspective of Society 5.0, HSI must develop problem-solving methods and tools that enable flexibility and resilience in case of unexpected, rare, and unknown events.

What developments in AI concern you the most?

AI develops knowledge and experience in intelligent human and machine multi-agent systems, which should be associated with systems of systems currently emphasised in systems engineering. Even if generative AI is a very interesting technology, it must be matured from an HSI perspective.

Technology changes, but human nature doesn't; what part of human nature impacts most heavily on human-centred design (HCD)?

Machines are becoming increasingly autonomous, and people have already started to interact with them as partners rather than tools. This is why trust and collaboration have become crucial factors. In our incrementally digital world, tangibility, whether physical and/or figurative, must be further explored and concretely considered. In addition, HSI addresses human autonomy by developing appropriate technology, organisations, and people's competencies. Finally, HCD must be revisited to consider living entities in general.

Could you explain your understanding of the 'science of artefacts'.

Our sociotechnical world becomes more interconnected every day. Therefore, its complexity increases exponentially, and, in the same way biologists study interconnected natural entities, HSI specialists study interconnected artificial entities (artifacts) and living entities. The science of artifacts is therefore developing as a mirror of life science. Humans are equipped with a cortex that provides them with capabilities of creativity, design, and engineering, which support the development of artifacts that represent human intelligence. The study of these artifacts enables us to better understand the evolution of societies, and hopefully provide insights that could nurture human welfare and nature preservation.

Where would you like to see the field of HSI in the next ten years?

HSI is vital to the development of Society 5.0. Consequently, we need to develop appropriate HSI education and training in various school and university programmes to make sure that future sociotechnical systems satisfactorily handle the safety, efficiency, and comfort of natural and artificial entities on planet Earth and beyond. Within the next ten years, HSI should become a discipline of its own to guide new generations in the construction of useful, sustainable, and nature-compatible artifacts.

FlexTech offers a Master's course on Human Systems Integration that is now taught at CentraleSupélec (Design and System Science), ESTIA (Aerospace and Data Science), ISAE-SUPAERO (French Aerospace Institute of Technology), and ESCP (Paris Business School). The Master's course includes both fundamental studies and practical training based on active participation with industrial partners in several HSI application fields, such as human space flight, lunar base design, future air combat systems, remote virtual air traffic control centers, small modular nuclear reactors, increasingly autonomous trains, oil & gas telerobotic systems, remote aircraft maintenance, and sociotechnical healthcare systems.

Society 5.0 will be based on Human Systems Integration.

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Further reading

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