First INCOSE Workshop on the Evolution of Human-Systems Integration

October 4-5, 2016 – Florida Institute of Technology, Melbourne, FL, USA

Contents

Purpose

We can define Human-Systems Integration (HSI) as a growing practice derived from the conjunction of Human-Centered Design (HCD) and Systems Engineering (SE). HSI puts people at the center of the design and development processes of complex systems. It is a humanistic approach that provides methods and tools for reducing the cost of system life cycles. HSI uses human-in-the-loop simulations in early design phases, as well as agile development and usability/usefulness testing to help reduce surprises at the time of deployment. This requires both creative/design thinking, and constant activity observation and analysis to discover emergent properties of the complex systems being developed.

The mission of INCOSE HSI Working Group (HSIWG) is to develop recommendations, guidelines and standards for improving HCD and SE. Human-centered designers are HSI architects. They work in concert with other SE engineers and managers to improve understanding and provide guidance in the design and development of complex life-critical systems. HSIWG's role is to further develop an understanding of organization design and management that can support HCD, as well as of modeling and simulation, advanced interaction media, complexity analysis, and cognitive engineering.

The purpose of this first HSI workshop was to gather worldwide specialists to share and discuss what HSI is about and plan for further HSI developments within INCOSE and beyond. More specifically, we started designing content to update INCOSE Systems Engineering Book Of Knowledge (SEBoK) and further down INCOSE Systems Engineering Handbook.

Presentations

We had four main scheduled presentations given by NASA JSC, MOD (U.K.), NASA KSC and FIT SHCDIA (School of Human-Centered Design, Innovation and Art). The slides of these presentations are provided in separate documents. Bonnie Novak, Human Systems Integration Scientist, Human Performance, Training, & BioSystems Directorate, Office of the Assistant Secretary of Defense for Research and Engineering, DOD (Department of Defense), gave an additional short presentation.

GEM session

We also had a GEM session (Group Elicitation Method) where we generated a series of viewpoints and concepts useful to better characterize the field of human-systems integration within systems engineering. GEM is a brainstorming method based on brainwriting, concept clustering, priority assignment and decision-making. It combines divergent thinking and convergent thinking.

During the workshop, participants were asked to provide their viewpoints (Appendix 3) on what Human-Systems Integration should become taking into account the evolution of technology and practices. They were also asked to take into account technological possibilities and societal evolution, as well as how they see human-centered design.

The following concepts were elicited.

Negative points:

1. Human-systems integration is not well organized (duplication should be avoided)
2. Human component of complex systems that are more interactive is not considered enough
3. HSI requires more training in Psychology and Cognitive Sciences for human use
4. Technologies are evolving faster than human societal practices. HSI models and approaches will not keep up with technology development. This is the reason why we need to develop a deeper approach of HSI.
5. HSI is currently driven by market and politics. It should be back to academia and human-centered designers.
6. Increasing focus on cognitive rather than physical on systems design. This implies that we should have a consistent and comprehensive approach to tangibility. There is a need for integrated models and frameworks.

Positive and desirable points:

1. Modeling and simulation (M&S) are crucial conceptual and technological tools for HSI. They contribute to make earlier prototypes more tangible and useful for successful designs.
2. HSI is strongly related to agile development, formative evaluation and participatory design.
3. HSI of the future should have a broad impact, and be transversally tangible and integrated. HSI architecture should be the core of every systems organization.
4. HSI is a collection of competencies in SE.
5. HSI generates requirements for systems and their use (e.g., maintenance should be taken into account, not only direct end-users).
6. HSI represents individuals, groups and organizations in which the system exists.
7. HSI practically useful in government and non-government environments
8. New technology in communication should be leverage to include users in design process.
9. HSI is mandatory
10. Increasing human technology will enhance problem solving skills within 10 years (Google glasses)
11. HSI is multi-disciplinary
12. HITLS is a central notion for HSI
13. HSI addresses safety, efficiency, quality, security, comfort, user experience in systems being developed (different types of specialties for design)

Action items:

- INCOSE should organize a task force with the mission of studying socio-technical evolution, innovation and other important issues.
- INCOSE should gather and integrate generic best practices. Lessons learned have to be put down.
- HSI should be imbedded in design processes like DNA
- Make HSI everyone's responsibility (safety, efficiency and comfort)
- HSI should provide a holistic model for SE, recognizing systems with human in the loop (or the opposite)
- HSI should provide support to shared understanding. Develop HSI Guidelines and checklists for engineering teams.
- HSI should provide design principles and procedures
- HSI should be a universal language across languages and cultures
- HSI should be considered as a leading discipline in SE
- Incorporate HSI in organization culture and consciousness. HSI should consider social changes, because people are becoming more technology savvy. We need to better understand societal changes to better anticipate future human-technology conditions
- HSI principles should be clearly defined
- Organization requires good management, understanding, funding, board of decision makers HSI as risk management
- HSI test-beds should run in parallel with current SE practice
- During the design, all shareholders should communicate using the same language or at least having a common frame of reference.
- HSI should incorporate and contribute to make evolve agency and organization structures requirements.
- We need to develop ontology for HSI and human-centered SE.
- HSI should be introduced in economics to have more impact and be recognized. HSI existence should be better justified, and show its benefits.
- HSI should be better integrated in systems engineering.
- Top management should be trained in HSI and HCD
- HSI should be used at the requirement level (HSI should be first step in design processes) as well as along the whole life cycle of a product. HSI should represent humans throughout life cycle of a product.
- How can we generalize HSI core to sell it to SE in a meaningful way?
- There should be an HSI plan for each project
- There should be greater connectivity, which implies complexity and emerging properties.
- Function allocation is a key process is HSI (definition of roles, contexts and resources).
- Further develop collaborative work and participatory design for HSI. Multi-disciplinary teams to generate collective power toward innovation. Human-in-the-

loop simulations (HITLS) should be prioritized when possible and affordable (ROI should be considered). Time planning is also a key factor.
- HSI involves a multi-disciplinary approach (i.e., all stakeholders considered during the design phase, as well as along the whole life cycle of a product)
- Develop visualization for HSI (i.e., we need to develop appropriate and effective visualization techniques that enable people to better understand how technology and people can work together to achieve a given goal)
- Human should be able to supervise systems – sense of control
- HSI should be holistic, i.e., take into account artifacts (systems) being designed and developed, users (people involved around these artifacts, associated tasks, related organizational environments, and various relevant situations where tests should be carried out.
- Participatory design: Adapt technology to take into account human needs; Customer should be part of the design process

Questions:

- What does successful HSI look like?
- Will HSI need a standardized language throughout industry toward industry standards? Do we need HSI ISO standard? Should we have more standardized processes for HSI?
- Should we take the risk of inventing a new discipline dealing with complexity instead of consolidating what we already have?
- Should we see HSI dealing with cooperative systems where machines and people are equally autonomous?
- Accountability in HSI?
- Should HSI address climate changes?
- How can HSI address biomedical systems integration (cyborg)?
- How can big challenges, such as Mars terraforming, galvanize technological advances?
- What kinds of HSI tools should be developed commercially?

Are we defining new discipline or introducing HSI to SE?

This question was at the center of the discussion during the workshop. It was illustrated by the description of the evolution of how human factors, and more specifically Human-Centered Design, are taken into account by various disciplines, as shown in Figure 1. After the Second World War (WW2), Human Factors and Ergonomics (HFE) developed as a corrective discipline (corrective ergonomics) after engineering. The main representative world organization for this discipline is the International Ergonomics Association (IEA). Then, human-computer interaction (HCI) and interaction design came into play, putting interaction with software-based systems on the spot. The main representative world organization for this discipline is the Association for Computing

Machinery (ACM) Special Interest Group on Computer Human Interaction (SIGCHI). More recently, association of Systems Engineering (SE) and Human-Centered Design (HCD) consolidated the emergence of Human-Systems Integration (HSI). The main representative world organization for this discipline is the International Council on Systems Engineering (INCOSE).

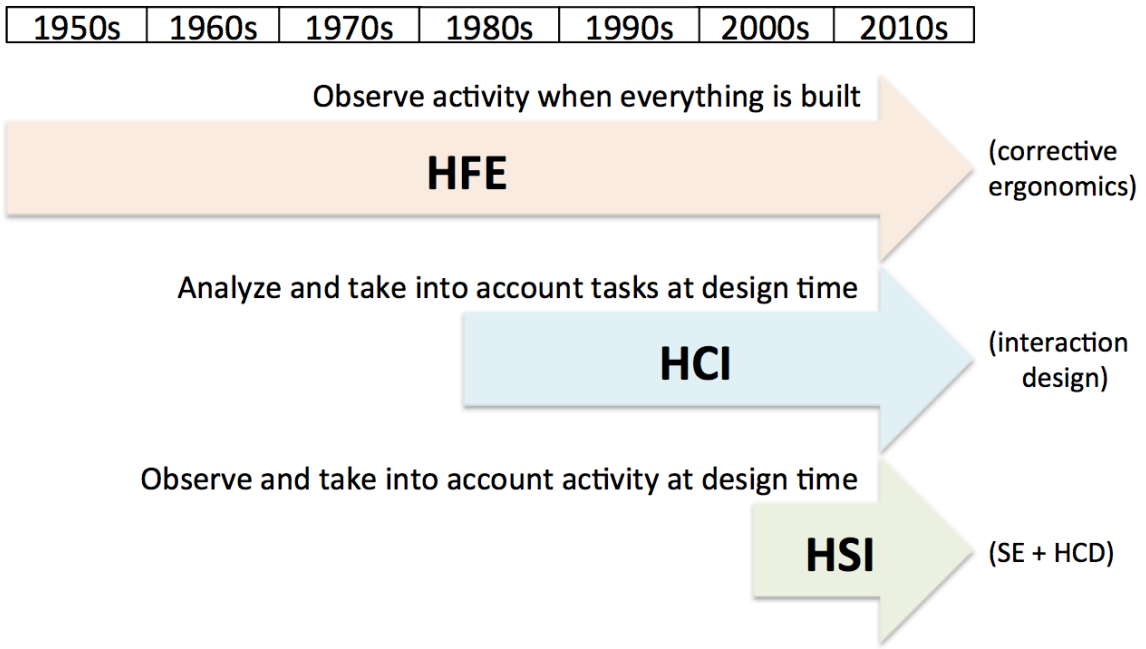

Figure 1. Human-centered design evolution (Boy, 2016).

During the workshop, we have listed a series of issues that require more attention and discussions during the next workshop to be held in Torrence, CA, early 2017.

We need to define HSI semantics

HFE and HCI have developed their own semantics over the years. Expanding to HSI, which assembles human-centered design and technology-centered systems engineering, requires the definition of more appropriate HSI semantics. HSI can be a component of systems engineering (as it is today) or a goal (i.e., systems engineering to could be to the service of human-systems integration).

We need to define what is a human-system architect

The opposite of HFE evaluators are HCD/HSI architects. The former operate after engineering has finished its work. The latter operate before engineering has started its work. Therefore, what is human-system architect's work? What are the role and scope of an HSI architect, as well as his/her required resources?

We need to update INCOSE's HSI charter

Obviously, HSI requires new definitions, processes and recommendations that will replace the current ones essentially based on corrective HFE only. It is important to consider the drastic evolution from the 20th century (going from hardware to software, where automation became an important issue) to the 21st century practices and tools (going from software to hardware, where innovation tangibility has become a crucial issue, e.g., what is human-centered 3D printing?). More specifically, HCD is now possible due to the fact that we have very credible modeling and simulation tools that enable human-in-the-loop simulations, which support testing from the early stages of design and development.

Conclusion and perspectives

We need to further discuss and develop HSI concepts. The HSI practitioner guide produced by NASA is a good example of a description of activities within a systems engineering framework. We need to get more example of current practice in HSI in various other industries. Theoretical accounts are also available.

HSI is a matter of culture that we need to better understand through experience feedback and analysis. INCOSE HSIWG (Human-Systems Integration Working Group) has the mission to explore this field and propose tangible descriptions and recommendations. HSI is a matter of inter-disciplinary work that should involve engineering, computer science, human and social sciences, management, architecture, design and arts.

HSI is a matter of innovation, where we need to distinguish between incremental and disruptive innovation. We also need to realize that innovation always break standards, which have to be constantly modified, together with changing people's behaviors and practices. HSI needs to take this into account, together with return on investment and time-to-market. This is the reason why organizational models are required, and developed to better master the orchestration of the various actors within the life cycle of a product.

HSI is a matter of complexity. INCOSE mainly focuses on complex systems that need to be managed by people. HSI complexity deals with autonomy, flexibility and maturity of the various systems being developed and managed. New principles have to be investigated and clearly defined. The mission of INCOSE HSIWG is right here!

We plan on organizing an INCOSE conference on HSI. An email distribution list will be established. An INCOSE HSI logo will be made.

Action items (short term):

- Form an active INCOSE HSI steering committee
- Organize a telecon on November 30, 2016
- Organize one or several HSI working sessions during INCOSE International Workshop, to be held on January 28-31, 2017, in Torrence, CA.

References

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Appendix 2. Agenda

Tuesday: Experiences Collection and Analysis

Morning:	08:30	Registration
	09:00	Problem statement
	09:30	NASA JSC experience, Christie Sauers, NASA JSC
	10:30	Break
	11:00	MOD contribution, Mark Anthony & Michael Boardman, Human Factors Integration Team Defense Science and Technology Laboratory
	12:00	Lunch
Afternoon:	13:30	NASA KSC contribution, Michael Conroy, NASA KSC
	14:30	DOD contribution
	14:45	FIT SHCDIA contribution, Guy A. Boy, FIT SHCDIA
	15:45	Break
	16:15	Analysis of HSI write-up (SE-Handbook & SEBoK)
	17:00	End discussions for the first day
	18:00	Dinner (for registered participants)

Wednesday: Ideation Solutions & Recommendations

Morning:	09:00	Creativity: generation of possible solutions (viewpoints)
	10:00	Rationalization: recommendations for SEBoK/SE-Handbook
	12:00	Adjourn
Afternoon:	Cancelled due to emergency (Hurricane Matthew)	

Appendix 3. List of viewpoints generated during the GEM session

1. HSI - needs to be better organized - we have too many documents, encouraging is that we have energy.
2. HSI advocates evangelist through organization
3. HSI metrics are refined best value proposition best practices
4. HSI is everyone's responsibility
5. HSI is holistic whole model approach to SE. HSI provides tools and tech for discovering integration with humans
6. HSI defined common understanding
7. HSI principles> foundation in design, processes and procedures.
8. HSI universal language across organizations and cultures
9. HSI - considered as leading as discipline in SE
10. -Creativity should be fostered in engineering
11. HSI is evolution of SE that revolutionizes the importance of human component of complex systems that are increasingly interactive
12. HSI - immersed in org culture and HSI consciousness
13. HSI principles should be clearly defined
14. HSI will be requiring more training in psychology and Cognitive sciences to get systems to human use
15. Organization needs management under for decision makers to understanding and focus commitments needs funding for decision makers
16. HSI is evolving more towards software safety software quality and security to be developed in systems
17. HSI testbeds should run in parallel with current SE practice
18. -HSI - During the design all the shareholders will have same language or common frame of references where they can interact with each other's without arguing
19. Future of org. will be more oriented to integrate HSI, will be more culture oriented as more diverse work of the future
20. M&S is crucial to HSI. Earlier prototypes will become more tangible. Practices defined as Rapid prototyping and TESTING.
21. HSI future - has broad impact, is transversally integrated, HSI as human system architecture, core of every technology system and organization
22. HSI - multi disciplinary approach is crucial related to organization, all stake holders has to be involved during the design phase
23. HSI should be strongly related to the agile development and formative evaluation and participatory design
24. HSI - need to access holistically> AUTOS, artifact, users, technology, organization, situation
25. HSI – just part of team closer relation between team of designers and end users to establish needs and direction

26. more focus on users because users are expected. HIS has to b transparent throughout the process as part of process. More focus on users
27. In companies we see HSI separation of HF into different types of specialties in Hardware, software and quality and experience group or design aspects
28. HSI – Customer leadership must understand and direct and be part of the process
29. HSI – incorporated formally in agencies organization structures
30. HSI – collection of competencies skill sets within SE. At Large to include logistics in engineering and planning
31. HSI – has to be introduced in economics to have impact and be recognized
32. HSI – do we need HSI standard or is ISO 9241 and others sufficient?<
33. Need an ontology for human centric systems engineering
34. HSI must consider social changes as well. Individuals are becoming more tech savvy and safety conscious
35. HSI – generates the requirements of systems, and safety systems how they will develop, evolve and how it will be replaced
36. HSI – new technologies in communication such as slack to be better integrated in to design process
37. HSI – how can we generalize the core of HESE in meaningful way to serve SE
38. How does successful HIS look like?
39. Grand challenges such as mars, terraforming, can galvanize human desire to better accommodate tech advances
40. What features of human societal changes do we need to understand to reliable predict human technology / conditions/ ten fifteen years out?
41. How does successful HIS look like commercial in non-governmental projects?
42. HSI will need a standardize language through about the industry to become through industry standard
43. HIS becomes the codification of the initial stands in the program – what is who trying to accomplish with the system
44. There is a danger in inventing new disciplines to deal with increased complexity rather than consolidate those we have
45. The best HIS support supporters and the lead system engineers of the program
46. HSI represents the humans within other systems throughout the lifes cycles from inception through retirement
47. HSI currently driven by market and politics; we start to implement in highlevel science and start to introduce it in academia not mainstraem
48. HSI represents the individual, team, organisation within which the system exists / operates
49. Tomorrow HSI is focused on how the system is organized in machines and systems.

50. HSI has to e better integrated in other engineering disciplines countre pressure HSI is notneed cause engineer took course
51. HSI captures the architecture, structure , formes, bones of the system design
52. How can we define HIS so that it is particularly useful in governmental and non-governmental environments
53. Technologies are evolving much faster than human society abilities to accommodate the tech changes
54. Future - pure HSI guidance documents
55. HSI – There are many HIS approaches as there are approaches_?
56. Can we depend upon disruptive technologies such as quantum computing to radically change technological capabilities in 25 years_?
57. HSI future ruled is orchestrated by NASA since we all need life-support
58. Can we build adequate human technology systems to reverses changes of global changes
59. Global disparities and wealth/health conditions will print ability new tech
60. Lessons learned has to be put down not just goods/ success
61. Pre phase A sims- HITL
62. How is INCOSE planning to change to cope with the future
63. Prediction – increasing human technology will enhance creativity / problem solving skills within 10 years / Google glass?
64. HIS should become first step forth and future design/ project
65. Design has to be done with HITL
66. Integrated solutions / cross-programs
67. More than just a suggestion: shall instead of wish / RQ
68. Solution dependent – tailor requirements by adding HSI
69. HIS is renamed to BSI – biological systems integration to allow for increased machine system complexity modeled as biological system includes biomimicry, which human and machine can't be no longer differentiated
70. More standardized processes for HSI
71. HSI is - accountability is key
72. HITL should be a central notion
73. HITL – T and E / V and V
74. Systems are design for humans – humans must be able to super vise the system, and have a sense of control over the subtasks
75. Top management should be trained in HSI and HCD
76. Integrated domains with SE framework
77. Guides / checklists for teams, requirements, readiness, design, VnV, etc.
78. HSI dressed at the requirements level
79. HSI should be shall not should standard process

80. More advances in HITL pre-phase in S M
81. Documented human inputs / reviews, tests, plans, requirements
82. Future -* HSI developed commercially tools for guiding projects through corp. where completed tasks and docs are recorded
83. Integrated models
84. Cross program and cross system / cross-project system integration
85. Integration amongst systems nad functionalities + software + facilities+ hardware + logistics + training tools +etc
86. User requirements as an formal early req. input
87. Pre-phase A involve humans – make it requirements
88. National / international level requirement / standards/ docs
89. Tomorrow HSI is a fundamental SE + design principle / methods approach
90. Specify HFE practitioners / expertise roles and involvement
91. User as BIOF – formal signature
92. Early in process – new methods to access – more visual
93. Today – tension for HIS but we do not see it in organization – tomorrow we introduce evaluation procedures, set of conditions could be used because there are no metrics to evaluate HCI
94. HIS will need to justify its existence and cost / benefits – we need to show benefits
95. Increasing focus on cognitive aspects of SE rather than physical / how do we specify this aspect of design in contracts
96. HSI will need to be able to contract able as well as HF and HIS req.
97. Human / AI team will change methods which HIS professionals will apply to systems problems
98. Greater connectivity of systems will lead to more complexity and emergent properties within the standard V process
99. HSI models and approaches will not keep up with emergent engineering process
100. Greater focus on humans safety / resulting from litigation
101. HSI will become more multidisciplinary and will interact with more disciplines in more interdisciplinary teams
102. Training for all should be intriguing and based on lessons learned and case studies
103. Every project develops and HSI plan and req. in earliest phase
104. Fundamental tool to design is the team how to organized competencies and keep design change
105. Convince top management we have to show the most important rules to do well - collective power to do well
106. Human evolution interactions to cross experiences nad competencies to be read to create new technology human first can create new tech

107. To organize the conditions to be relaxed in the unpredictable future – creative – way to safety
108. Change design we have to integrate multi-disciplinary team engineering and human sciences too
109. HSI as a plan focus on real human activity to more safety and innovation
110. To change design project we have to work about best conditions between designers and users methodological involvement human techniques
111. HSI as an approach to human need and possibilities and adapt technology for this