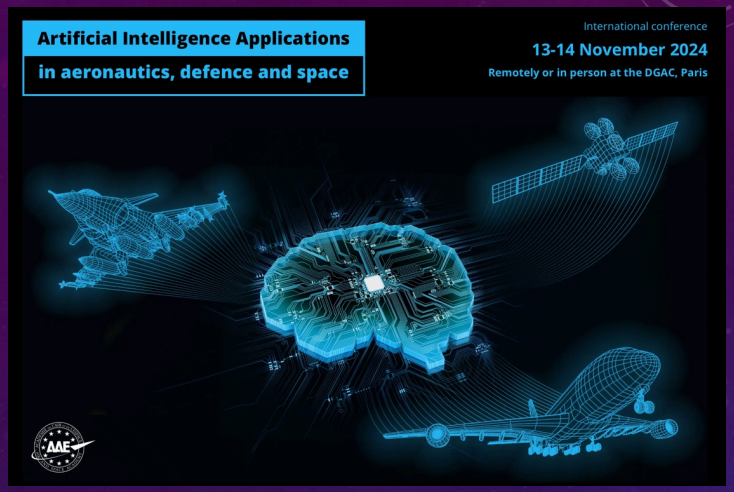


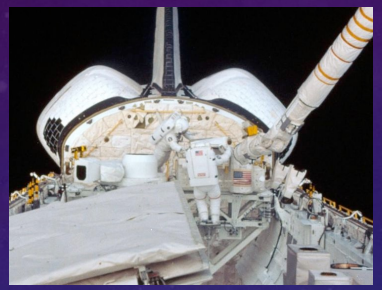
HUMAN - AI TEAMING

A HUMAN SYSTEMS INTEGRATION (HSI) APPROACH

Prof. Guy André Boy

FlexTech Chair Holder (CentraleSupélec & ESTIA)
Fellow of the Air & Space Academy
Fellow of INCOSE

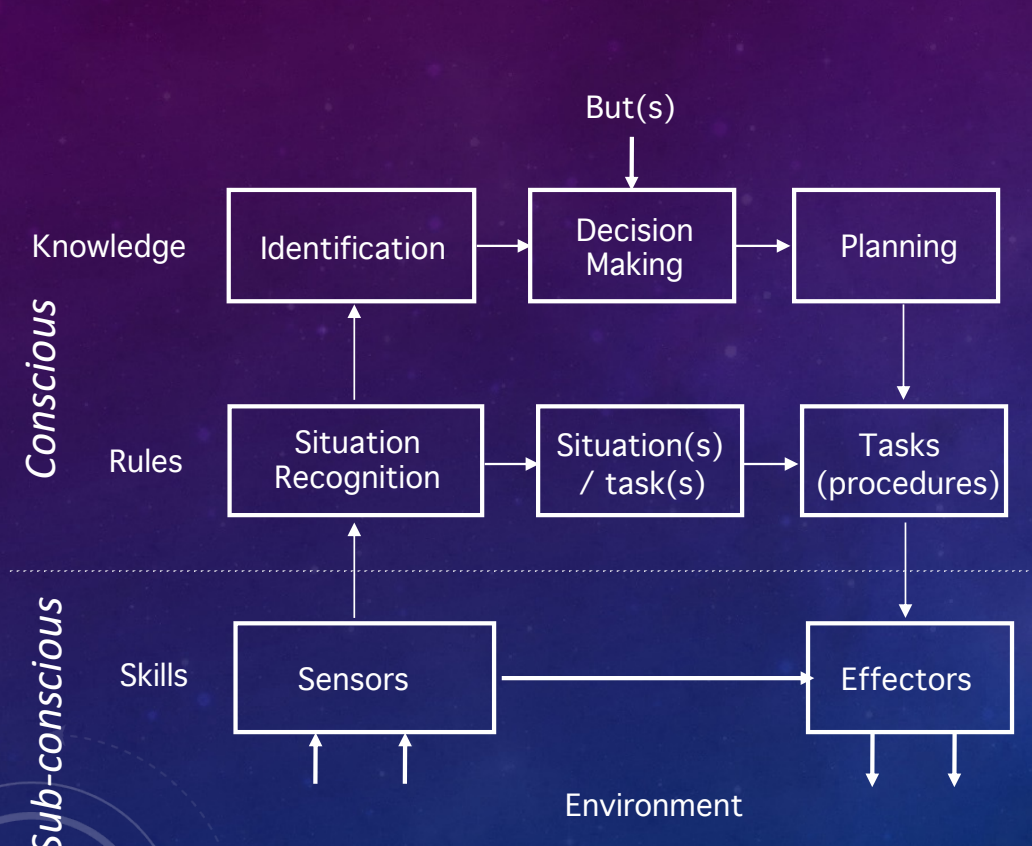
MY WORLD FOR ~45 YEARS…

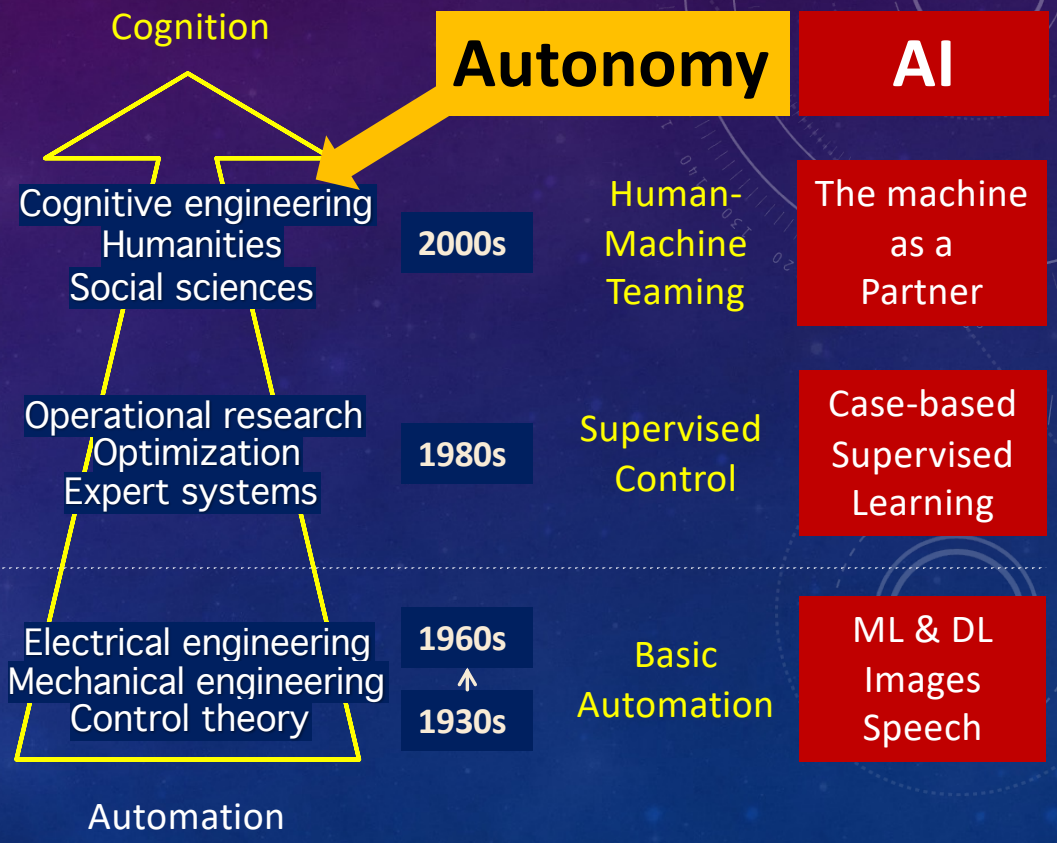


From correction…
… to interaction
… to integration

… and other things

PEOPLE, AUTOMATION & ARTIFICIAL INTELLIGENCE (AI)?





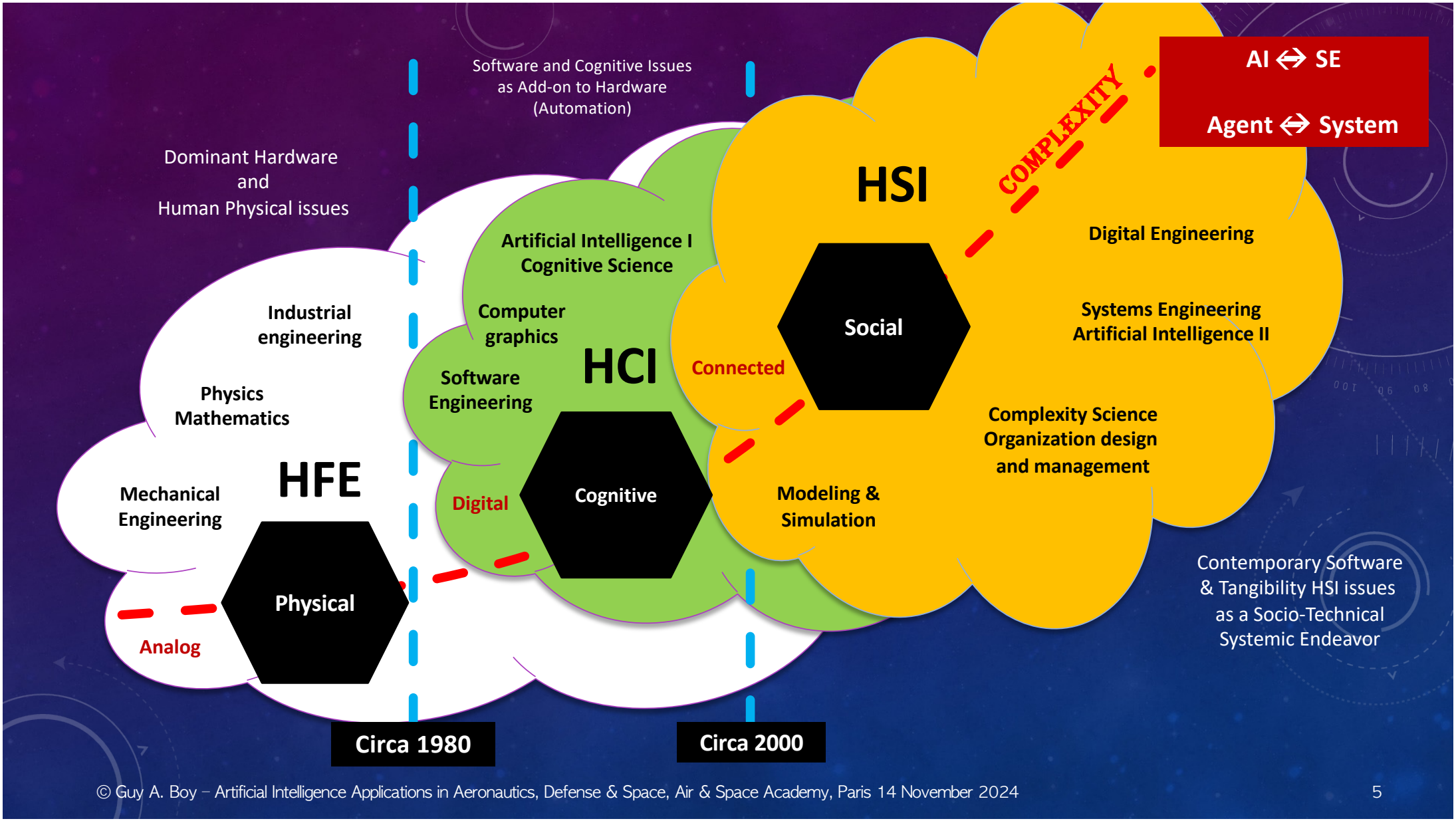
PEOPLE, AUTOMATION & ARTIFICIAL INTELLIGENCE

↓

FROM AUTOMATION TO COGNITIVE SYSTEMS

↓

SOCIOTECHNICAL SYSTEMS EVOLUTION
FROM PHYSICAL TO COGNITIVE TO SOCIAL?


Software and Cognitive Issues
as Add-on to Hardware
(Automation)
Dominant Hardware
and
Human Physical issues
AI ⇔ SE
Agent ⇔ System
COMPLEXITY
HSI
Digital Engineering
Systems Engineering
Artificial Intelligence II
Artificial Intelligence I
Cognitive Science
Computer
graphics
Industrial
engineering
Social
Connected
HCI
Software
Engineering
Physics
Mathematics
Complexity Science
Organization design
and management
HFE
Mechanical
Engineering
Digital
Cognitive
Modeling &
Simulation
Physical
Analog
Contemporary Software
& Tangibility HSI issues
as a Socio-Technical
Systemic Endeavor
Circa 1980
Circa 2000

AI4SE & SE4AI

A HUMAN & MACHINE MULTI-AGENT APPROACH…

AI: Artificial Intelligence
SE: Systems Engineering

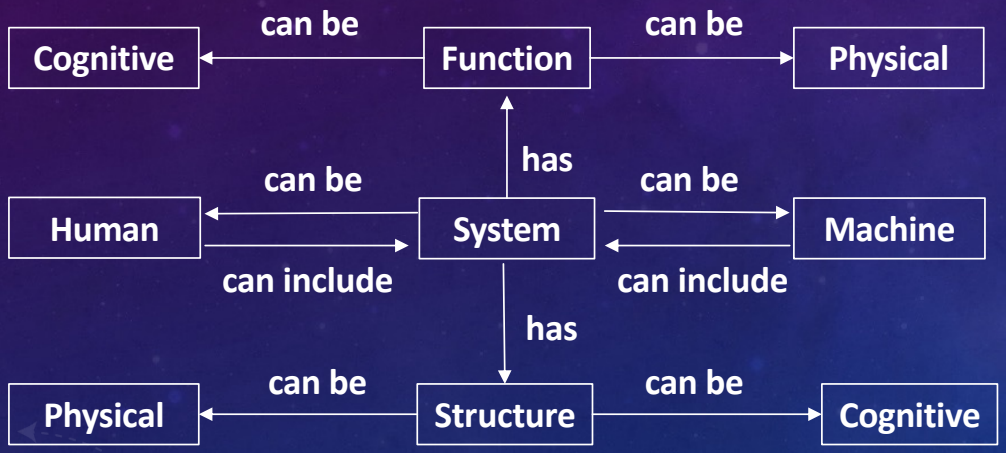
AI4SE & SE4AI

- AI complementing SE, and vice versa
  - Human vs. machine competencies (situation awareness, decision-making, action-taking)
  - Human-machine cognitive function allocation
- AI and SE are similar, e.g., multi-agent systems are systems of systems
  - In a sociotechnical system (STS), there are human and machine agents
  - Who is in charge?
- Socio-cognition, socio-ergonomics & social systems
  - Trust, collaboration, and operational performance
  - Authority, responsibility, and accountability
- Digital Engineering & Society 5.0
  - Human systems integration is possible during the whole life cycle of the STS
  - Tangibility has become a crucial issue
  - Human-AI Teaming certification/qualification?
  - Dealing with the unexpected

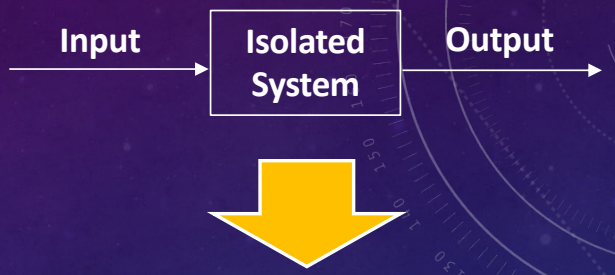
Boy, G.A. (2024). PRODEC: A Method and platform. For Human Systems Integration of Human-AI Teams. The fifth annual AI4SE & SE4AI workshop is sponsored and organized by the U.S. Army DEVCOM Armaments Center Systems Engineering Directorate and the Systems Engineering Research Center (SERC), at George Mason University, Arlington Campus, Arlington, VA, USA

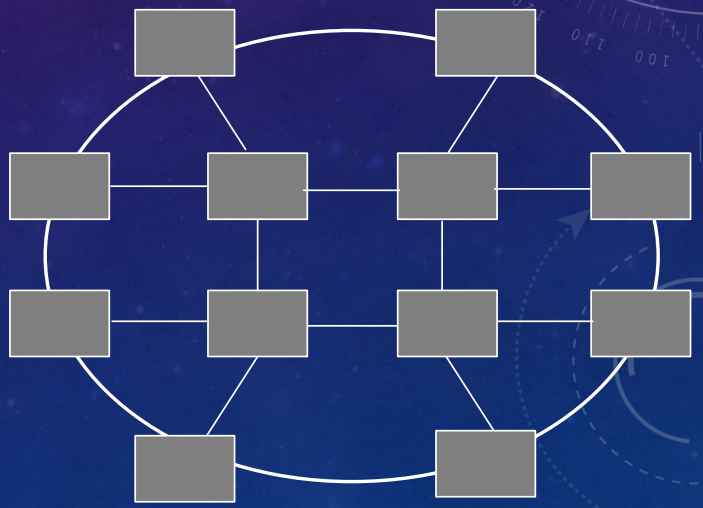
SE4AI & AI4SE

- AGENT VS. SYSTEM
- MULTI-AGENT (AN AGENT AS A SOCIETY OF AGENTS) VS. SYSTEM OF SYSTEMS
- AGENT/SYSTEM → STRUCTURE & FUNCTION (ROLE, CONTEXT, RESOURCES (SUB-SYSTEMS))
- AGENT/SYSTEM CAN BE HUMAN AND/OR MACHINE (HARDWARE & SOFTWARE)



Systems represent Humans and Machines…





Interconnected System of Systems

SE4AI & AI4SE

- AGENT VS. SYSTEM
- MULTI-AGENT (AN AGENT AS A SOCIETY OF AGENTS) VS. SYSTEM OF SYSTEMS
- AGENT/SYSTEM → STRUCTURE & FUNCTION (ROLE, CONTEXT, RESOURCES (SUB-SYSTEMS))
- AGENT/SYSTEM CAN HUMAN AND/OR MACHINE

HSI Metrics:

- **Shared Situation Awareness**
- **Trust & Collaboration**
- **Speed & Precision**
- **TOP Maturity**
- **Resilience**
- **…**

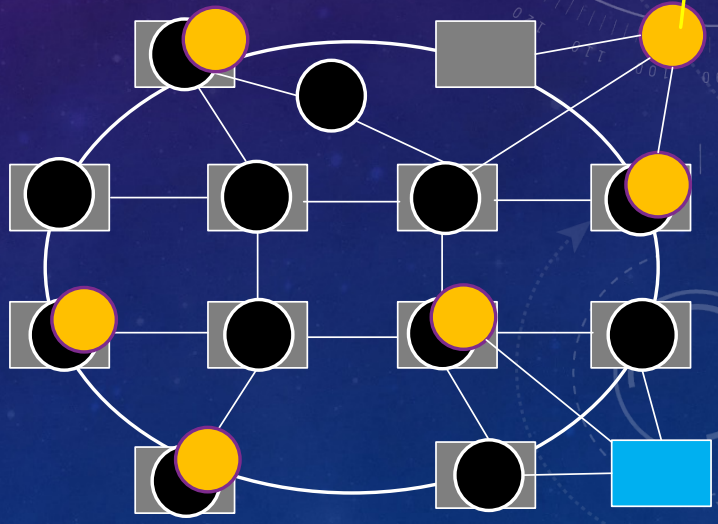
Interconnected Functions of Functions

Potentially, creating new people's jobs

Emergent Structures

Emergent Functions

Overlapping Functions of Functions



Interconnected Structures of Structures

SE4AI & AI4SE

- AGENT VS. SYSTEM
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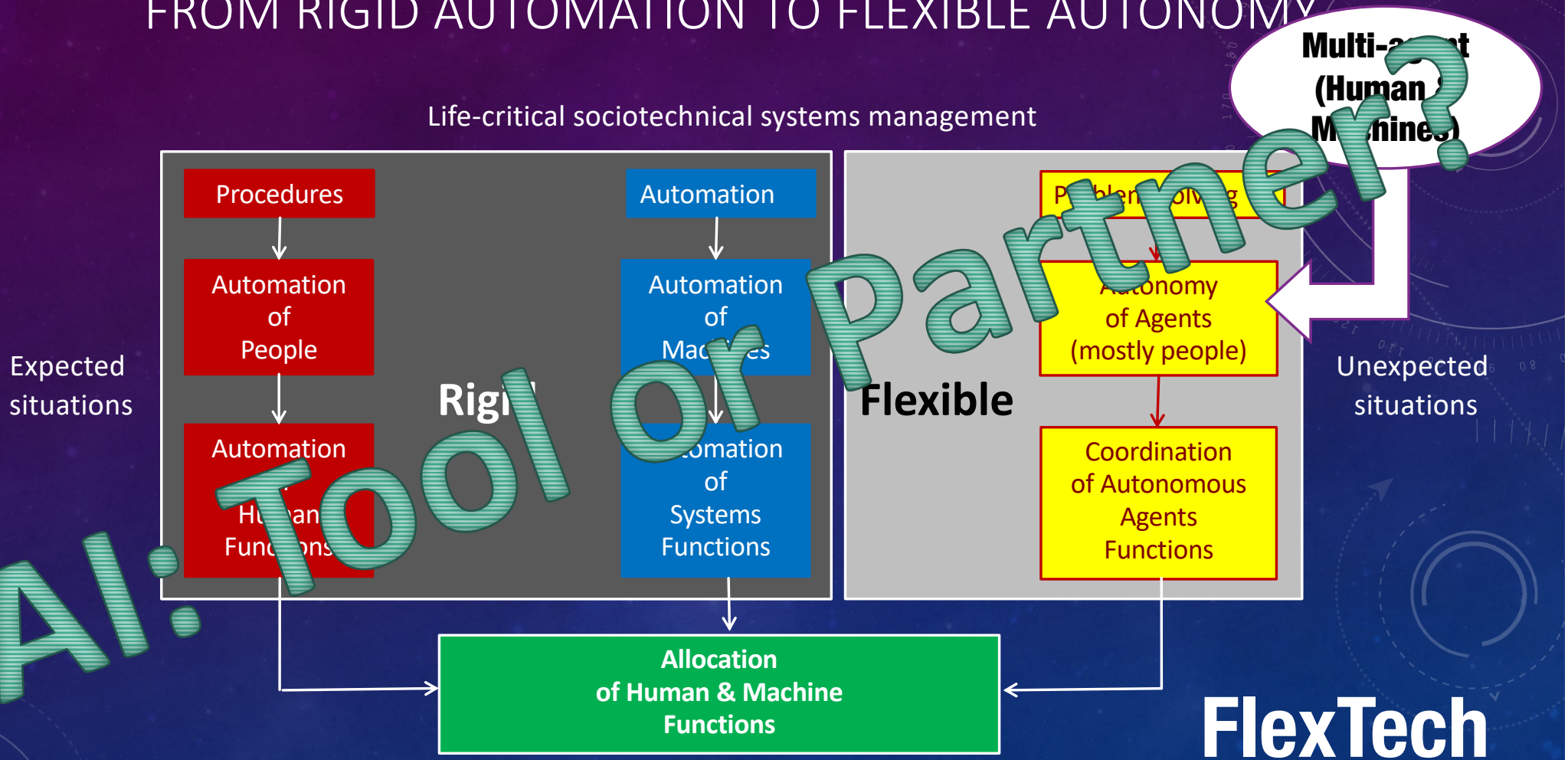
- AGENT/SYSTEM CAN HUMAN AND/OR MACHINE

SOCIO-COGNITIVE
V
HOW DO WE MANAGE COMPLEX SYSTEMS?

FROM RIGID AUTOMATION TO FLEXIBLE AUTONOMY

Life-critical sociotechnical systems management



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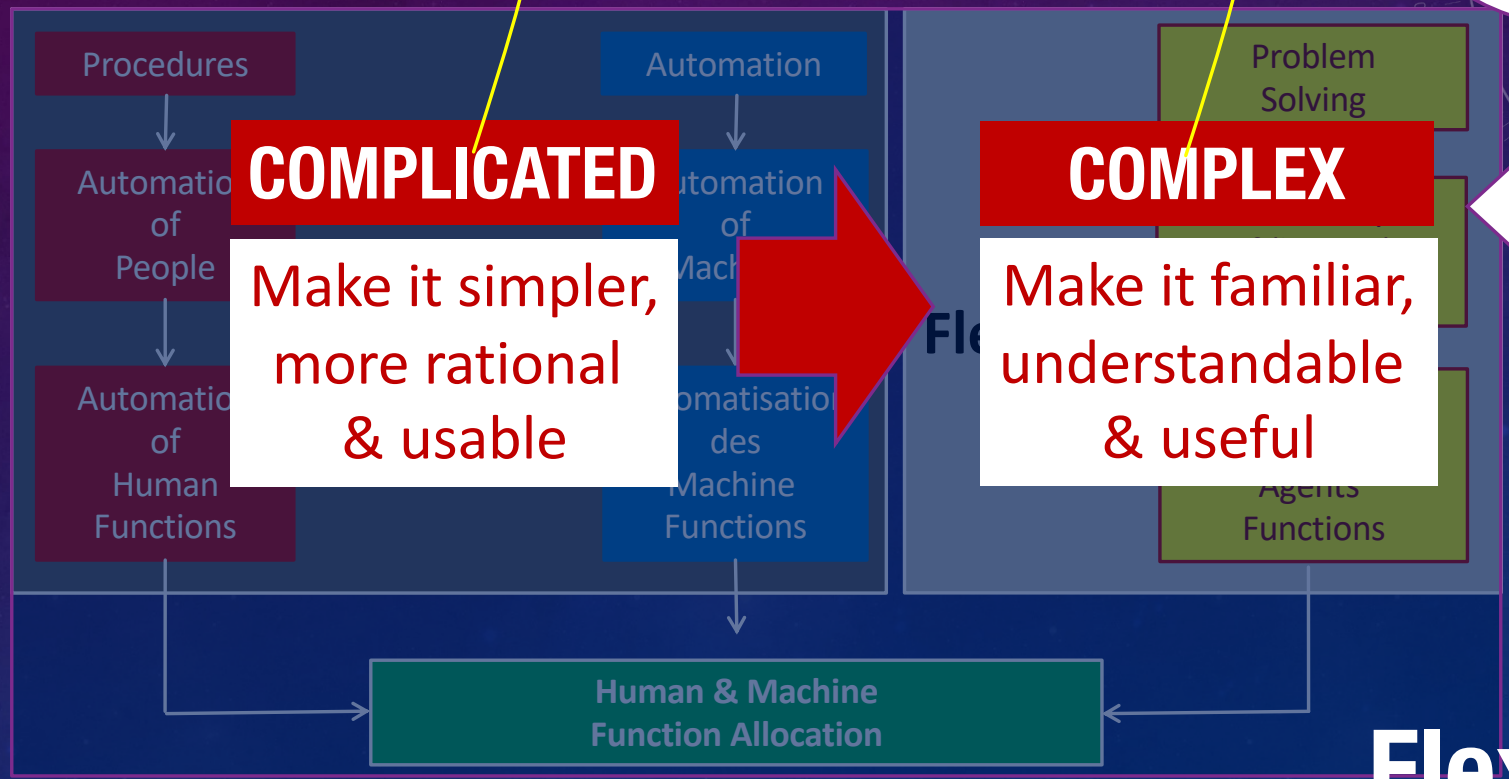
FROM RIGID AUTOMATION TO FLEXIBLE AUTONOMY

Reductionist approach

Involves Maturity

Multi-agent (Human & Machines)



Expected Situations

Unexpected Situations

https://www.sciencedirect.com/science/article/pii/S0160791X23001033

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READINESS LEVELS

Technology (TRL)

Human (HRL)

HRL	Description
1	Relevant human capabilities, limitations, and basic human performance issues and risks identified
2	Human-focused concept of operations defined and human performance design principles established
3	Analyses of human operational, environmental, functional, cognitive, and physical needs completed, based on proof of concept
4	Modeling, part-task testing, and trade studies of user interface design concepts completed
5	User evaluation of prototypes in mission-relevant simulations completed to inform design
6	Human-system interfaces fully matured as influenced by human performance analyses, metrics, prototyping, and high-fidelity simulations
7	Human-system interfaces fully tested and verified in operational environment with system hardware and software and representative users
8	Total human-system performance fully tested, validated, and approved in mission operations, using completed system hardware and software and representative users
9	System successfully used in operations across the operational envelope with systematic monitoring of human-system performance

Organization (ORL)

ORL-0	First principles where potential organizational models are explored.
ORL-1	Goal-oriented research that requires making choices from first principles to practical fully digital organizational setups
ORL-2	Proof of principle development, and active R&D is started in a virtual environment
ORL-3	Virtual agile organizational prototype development and first HITLS (virtual HCD)
ORL-4	Proof of organizational concept development using concrete scenario-based design from fully virtual to more tangible environments
ORL-5	Assessing organization capability in terms of authority sharing (responsibility, accountability and control), trust, collaboration and coordination, for example
ORL-6	Real-world use-case tests in a wider variety of situations - tangibilization continues
ORL-7	Practical integration with respect to criteria such as safety, efficiency and comfort, at various levels of granularity of the organization – tangibilization continues
ORL-8	Readiness for effective implementation on a real site (fully tangible) based on personnel feedback for deployment approval
ORL-9	Deployment involving both personnel and real machines

MACHINE LEARNING READINESS LEVELS?

https://www.sciencedirect.com/science/article/pii/S0160791X23001033

HOW CAN WE INCREASE MATURITY?

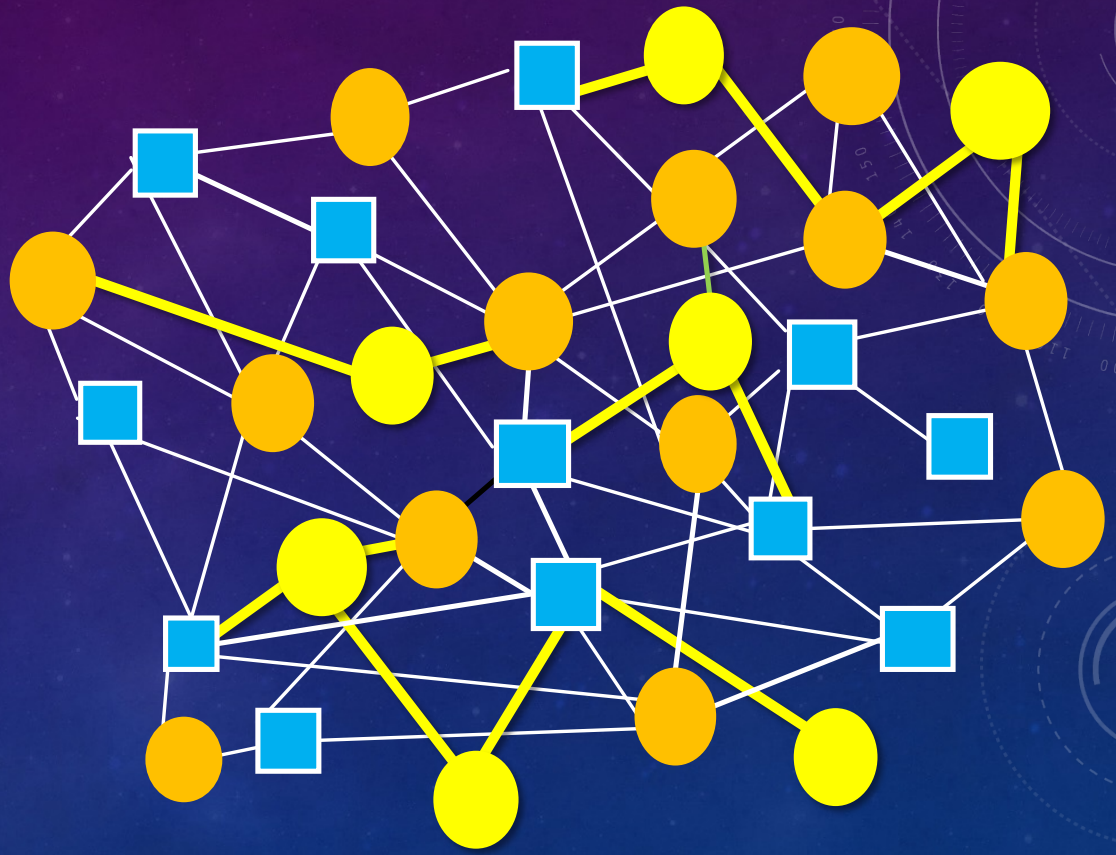
THE T.O.P. MODEL…
… IN HUMAN SYSTEMS INTEGRATION (HSI)

COMPLEX HUMAN & MACHINE SYSTEMS TESTING

Separability
a crucial issue

Complexity
in connections
as well as
in agents/systems themselves

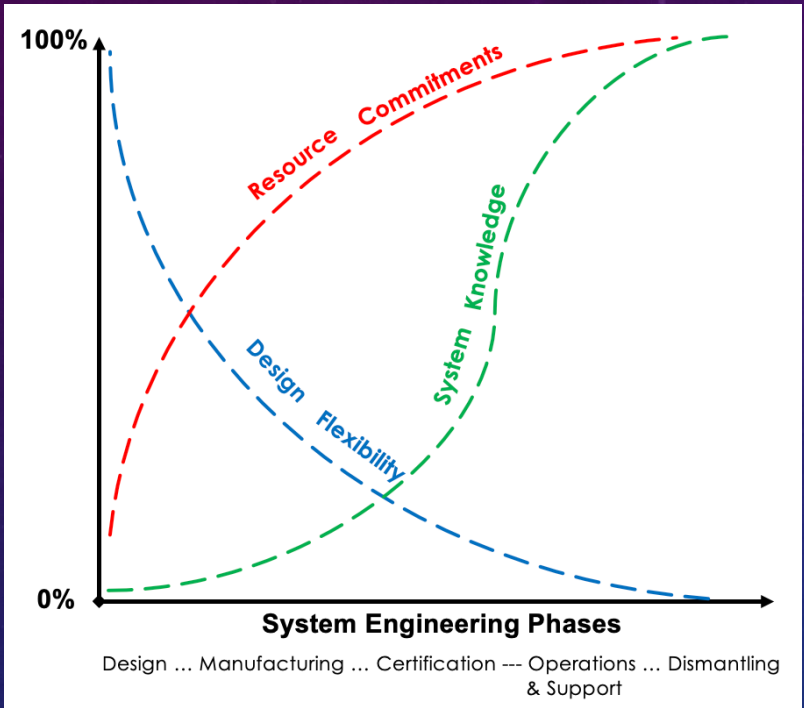
Emergent functions,
Coordination rules
and
the **maturity** issue



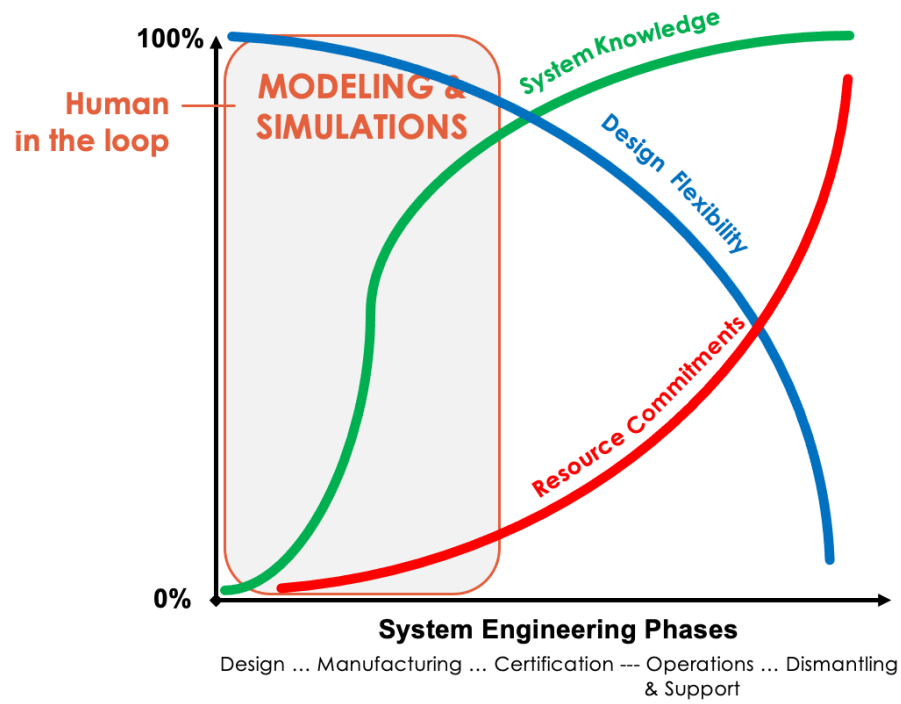
… therefore, this is a living organism

LIFE-CYCLED HUMAN SYSTEMS INTEGRATION…

Technology-centered

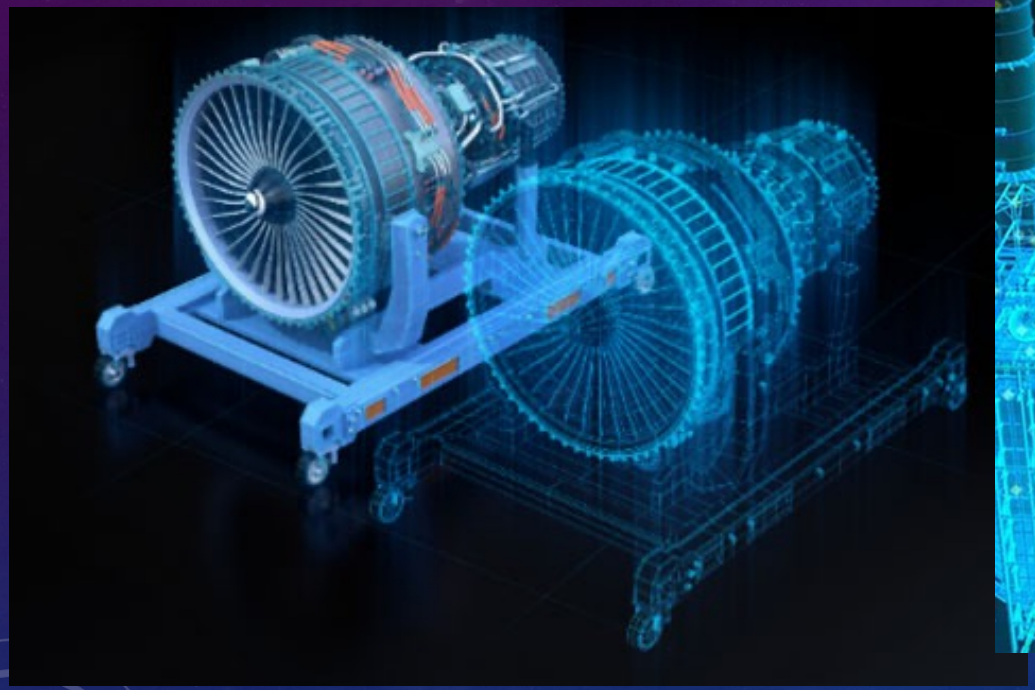


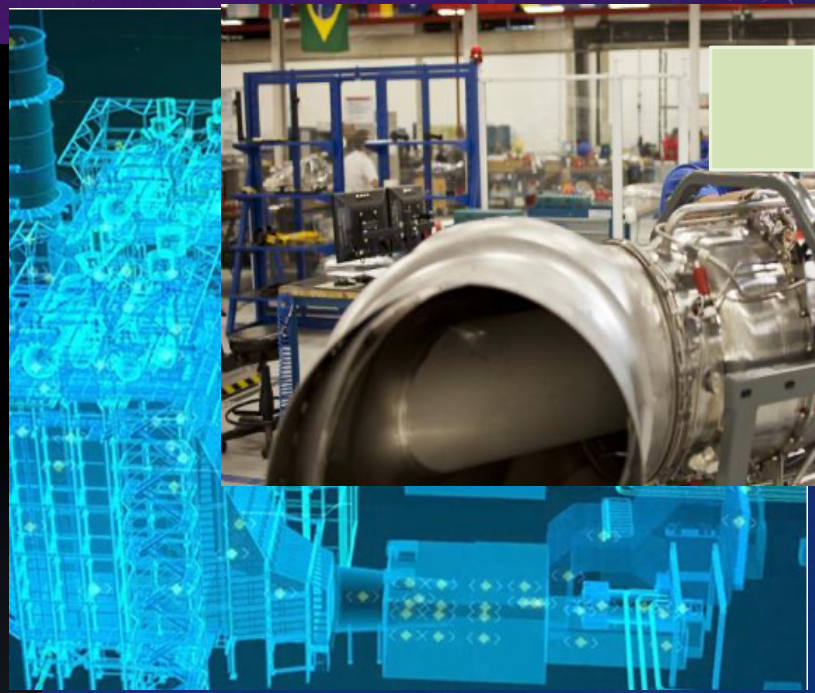
Human-centered



HUMAN-CENTERED DESIGN OF A DIGITAL TWIN FOR HELICOPTER ENGINE MAINTENANCE

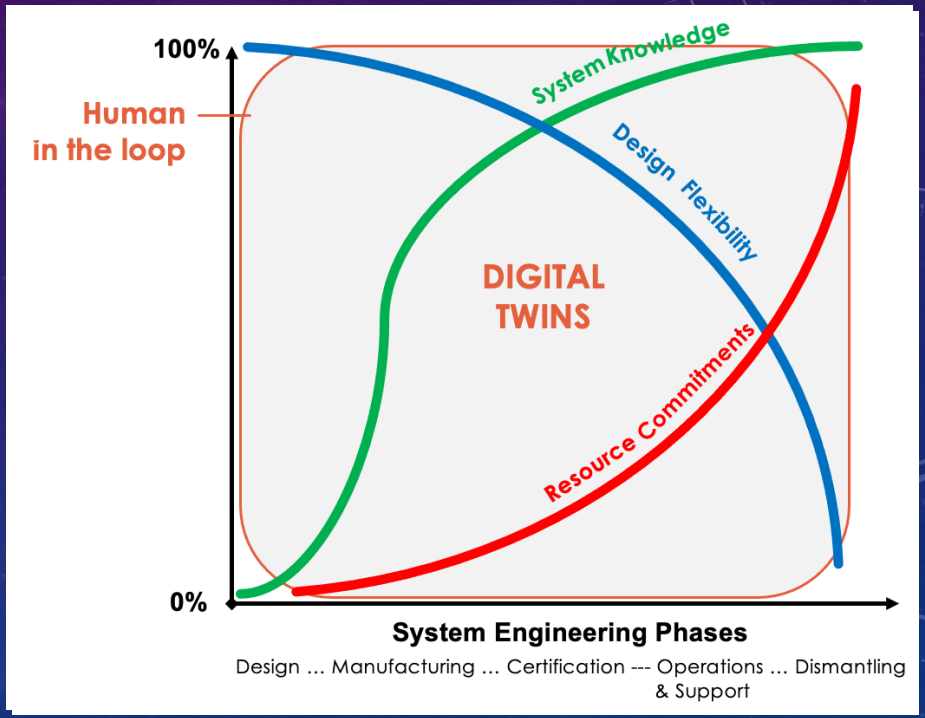
FlexTech





DIGITAL TWINS

- Extending human-in-the-loop simulations
  - Throughout the life cycle
  - “what if?”
- Active documentation
  - Integration of experience feedback (ML)
  - Organizational memory (case-based)
- Digital twins as virtual assistants
  - Collaborative multi-agent systems
  - Mediators for collaborative work



FROM TECHNOLOGY-DRIVEN ENGINEERING…

… TO HUMAN SYSTEM INTEGRATION

↑

SOCIO-COGNITIVE

FROM TANGIBLE TO VIRTUAL

Engineering

Ergonomics
Automation

Factors
Human

Tangible
Traditional Engineering

Physical Environment

Real
Human agents

Real
Machine agents

Space for
Control & Management

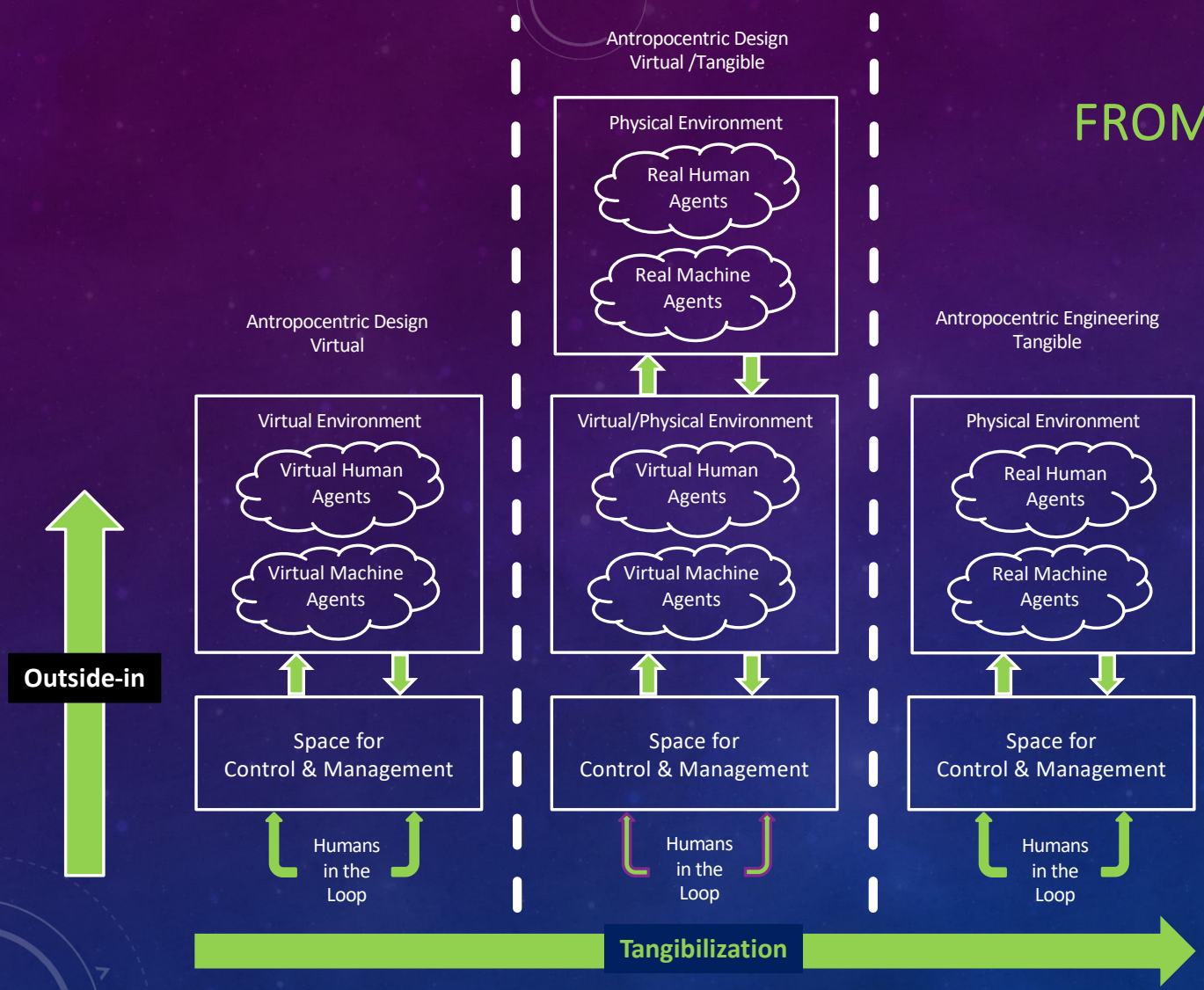
Humans
in
the
Loop

Inside-out

20TH CENTURY APPROACH

Engineering,
Ergonomics,
HCI &
Automation

FROM VIRTUAL TO TANGIBLE



21ST CENTURY APPROACH

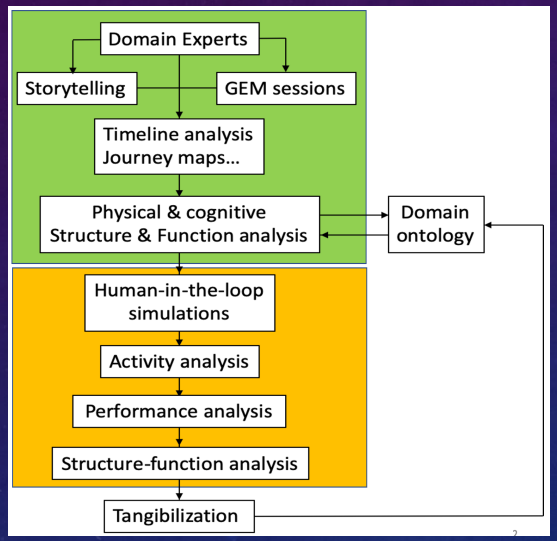
HSI

Digital Engineering
Tangibility management

OFF-SHORE MULTI-AGENT TELEROBOTIC SYSTEMS

FlexTech

PRODEC method combined with human-in-the-loop digital simulation



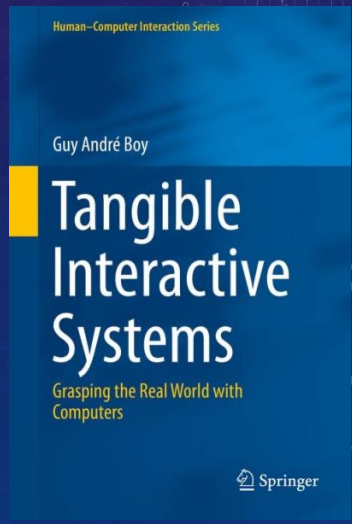
Tangibilization

TANGIBILITY: SYSTEMIC ATTRIBUTES

- Complexity: separability, interconnectivity, collaboration, trust, ...
- Maturity: TRLs & HRLs & ORLs
- Flexibility (design & operations): safety modes, reversibility, FlexTech, ...
- Stability/Resilience: passive vs. active, resilience, crisis management, ...
- Sustainability: design rationale, knowledge management, ...

+ Sociotechnical Factors

Shared situational awareness
Cooperative decision-making
Harmonized risk-taking
Trust and collaboration



SOCIO-COGNITION

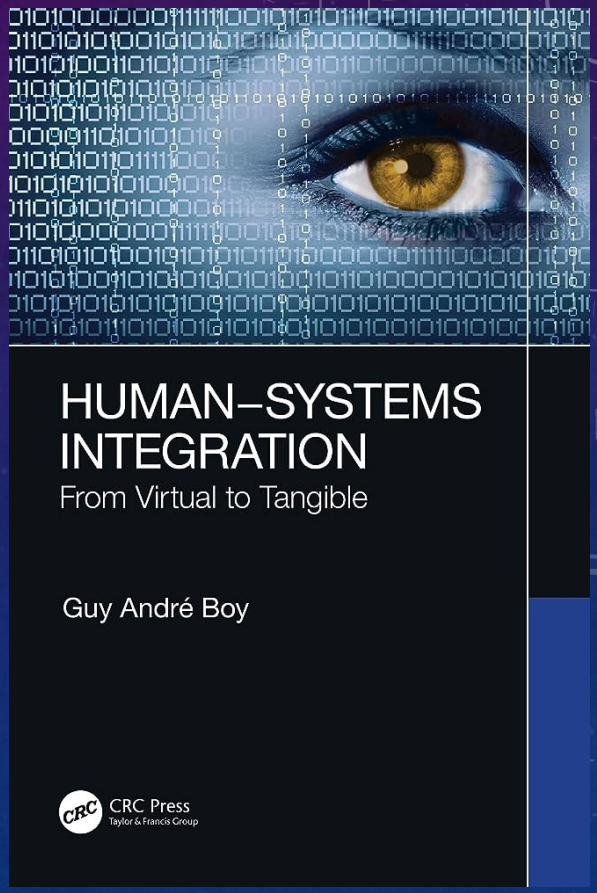
V

WHY DON'T WE TALK ABOUT ~~AUGMENTED COGNITION~~ INSTEAD OF ARTIFICIAL INTELLIGENCE?

REFERENCES

- Boy, G.A., Masson, D., Durnerin, E. & Morel C. (2024). PRODEC for Human Systems Integration of Increasingly Autonomous Systems. Systems Engineering Journal. Wiley, USA. DOI:10.1002/sys.21751. (https://authorservices.wiley.com/api/pdf/fullArticle/17929898)
- Boy, G.A. (2023). An epistemological approach to human systems integration. *Technology in Society Journal*, 102298. https://doi.org/10.1016/j.techsoc.2023.102298
- Boy, G.A. (2023). Uncertainty management in human systems integration of life-critical systems. In Griffin, Mark A., and Gudela Grote (eds). The Oxford Handbook of Uncertainty Management in Work Organizations (online edn, Oxford Academic, 20 Oct. 2022), Oxford University Press, UK, accessed 6 Dec. 2022.
- Boy, G.A. (2022). Model-Based Human Systems Integration. In the Handbook of Model-Based Systems Engineering, A.M. Madni & N. Augustine (Eds.). Springer, USA. DOI: https://doi.org/10.1007/978-3-030-27486-3_28-1.
- Boy, G.A. (2021). Design for Flexibility - A Human Systems Integration Approach. Springer Nature, Switzerland. ISBN: 978-3-030-76391-6.
- Boy, G.A. (2021). Socioergonomics: A few clarifications on the Technology-Organizations-People Tryptic. Proceedings of INCOSE HSI2021 International Conference, Wiley Online Lib.
- Boy, G.A. (2020). *Human Systems Integration: From Virtual to Tangible*. CRC Press – Taylor & Francis Group, USA (https://www.taylorfrancis.com/books/9780429351686).

THANK YOU!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