Human-AI Teaming

FlexTech International Industrial Spring School

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HUMAN SYSTEMS INTEGRATION IN THE DESIGN OF INCREASINGLY AUTONOMOUS SYSTEMS

Introduction...

Prof. Guy André Boy

Fellow of the Air & Space Academy
Fellow of the International Academy of Astronautics
INCOSE Fellow & HSI WG Chair
IEA Aerospace TC Chair
Senior Member of the ACM

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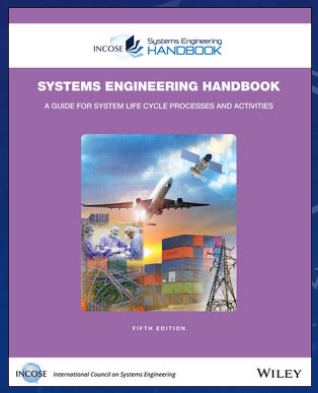
HUMAN-AI TEAMING

- Individuals and groups interacting within a system of interest (SoI)
- "Stakeholders": operators, users, customers, owners, maintainers, trainers, support personnel and the general public
- Cooperative and non-cooperative people
- Defined a priori and discovered as emergent stakeholders

people...



HUMAN-AI TEAMING

Systems that demonstrate intelligent behavior
by perceiving and analyzing their environment and taking action
– with some degree of autonomy – to achieve specific goals

- **Purely software, acting in a virtual world**

  (e.g., any kind of automatic alarm assistants, reasoning systems, search engines, data analysis, speech or image recognition, machine learning, etc.)

- **Incorporated into hardware devices**

  (e.g., advanced robots, semi-autonomous cars, drones, or Internet of Things)

Algorithms...

HUMAN-AI TEAMING

- Behavioral levels of teaming: Tool or Partner?
- Cohesion, regulations & common interest
- Small team, organization & community
- Delegation, management & situation awareness
- Systemic interaction models (supervision, mediation, cooperation)

HUMAN-AI TEAMING

Work design
Intrinsic motivation
& competence development

Technology design
Human in the (control) loop

Organizational design
Regulation & Coordination

HAT: Human-AI Teaming
HSI: Human Systems Integration

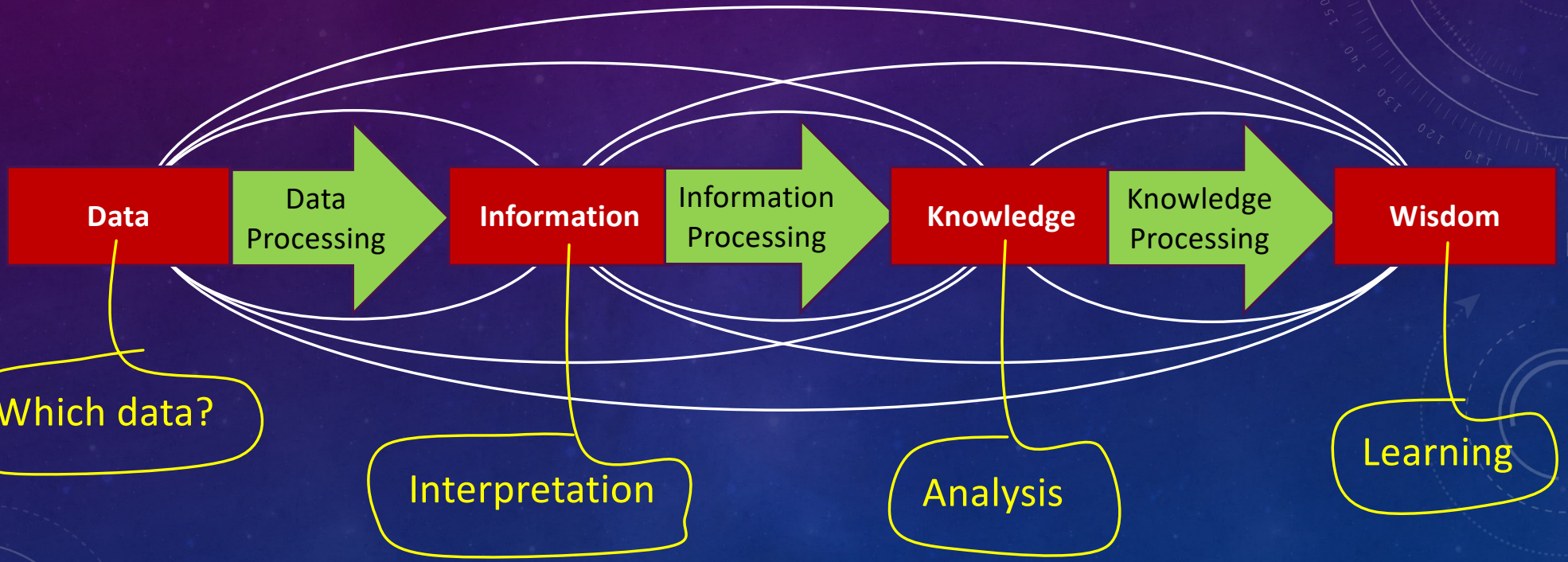
GENERAL HAT REQUIREMENTS

- Observability
- Predictability
- Directing Attention
- Exploring the Solution Space
- Adaptability
- Directability
- Calibrated Trust
- Common Ground
- Cooperation & Collaboration
- Information Presentation
- Design Process

Trust, Collaboration & Operational Performance

CONCEPTUALIZATION

Objective vs. Subjective

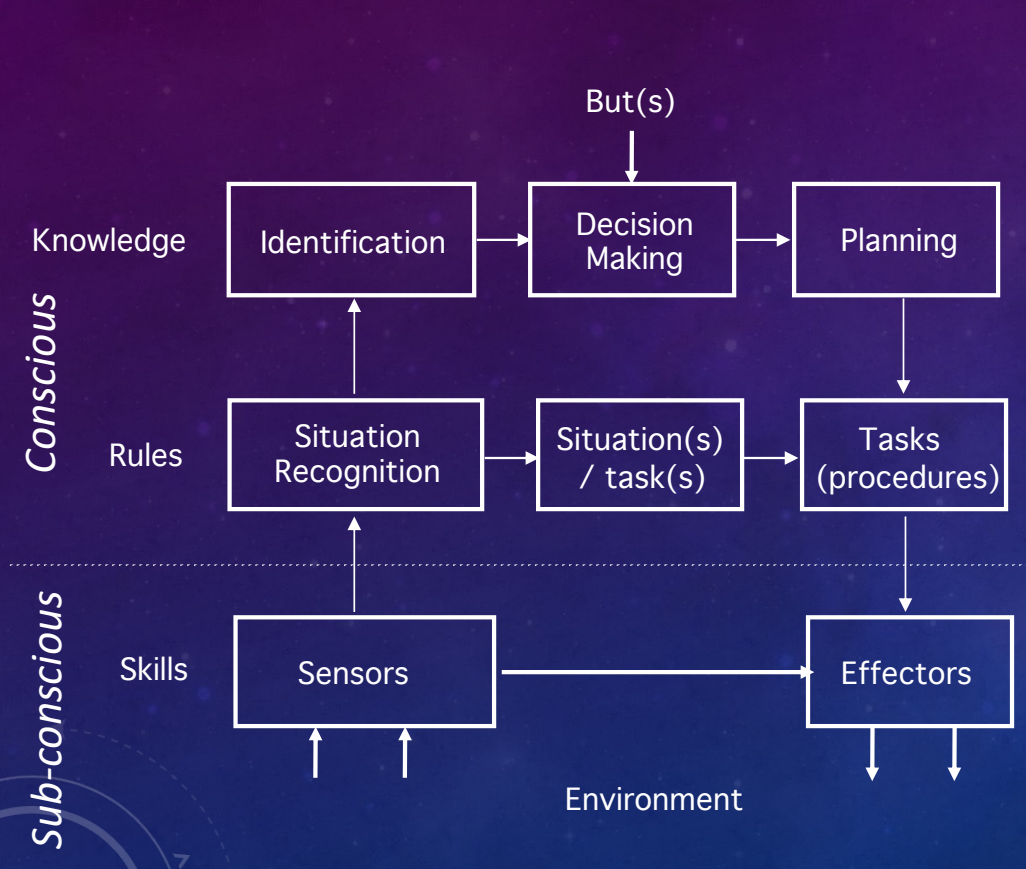


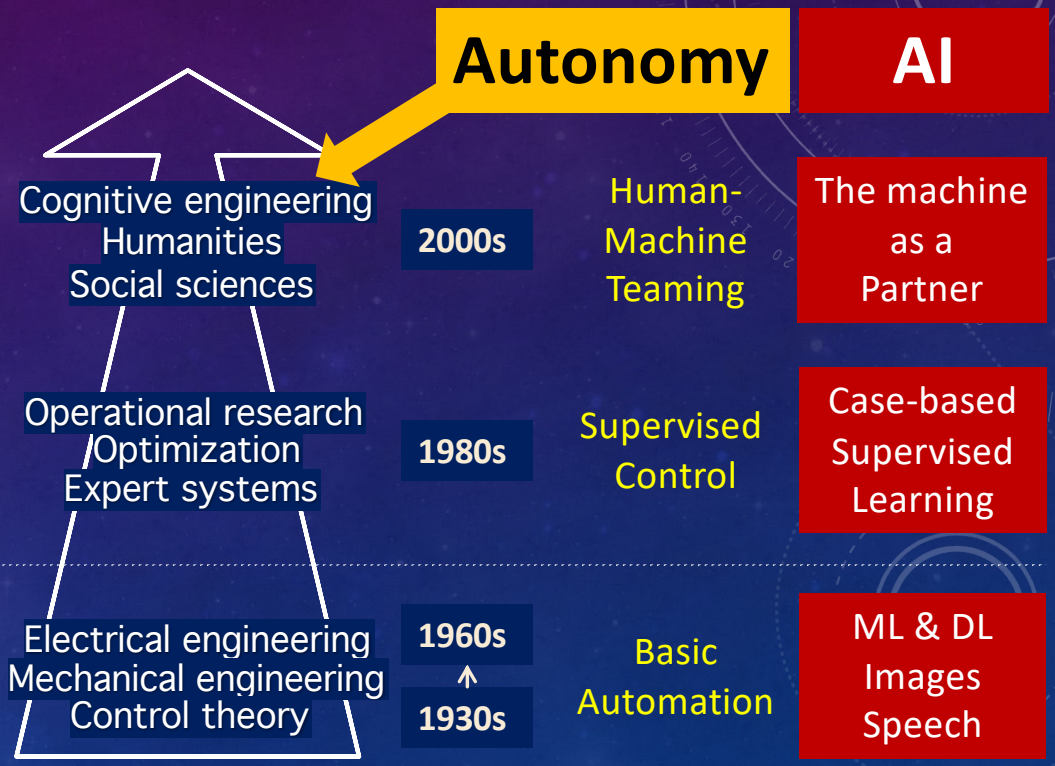
NUMERICAL VS. SYMBOLIC ARTIFICIAL INTELLIGENCE

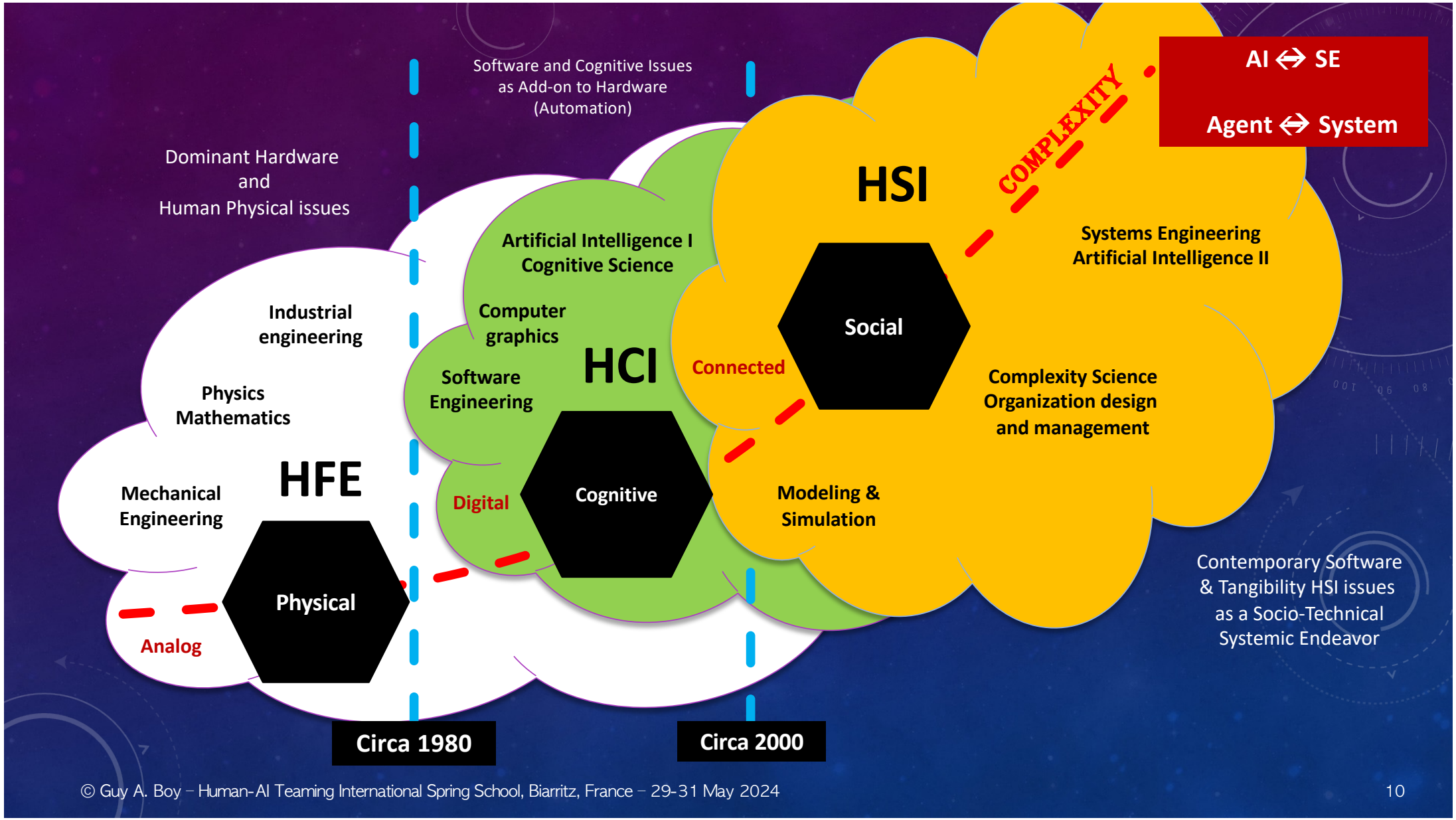
- Statistics vs. Logic
- Neuronal Networks vs. Expert Systems
- Machine Learning
- Intuition vs. Rationality

Intuition is the ability to acquire knowledge, without recourse to conscious reasoning or needing an explanation – Wikipedia

WHAT DO WE MEAN BY ARTIFICIAL INTELLIGENCE (AI)?






Software and Cognitive Issues
as Add-on to Hardware
(Automation)
Dominant Hardware
and
Human Physical issues
AI ⇔ SE
Agent ⇔ System
COMPLEXITY
HSI
Artificial Intelligence I
Cognitive Science
Systems Engineering
Artificial Intelligence II
Industrial
engineering
Computer
graphics
Social
HCI
Connected
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

- AI complementing SE, and vice versa
- AI and SE are similar, e.g., multi-agent systems are systems of systems
- Socio-cognition, socio-ergonomics & social systems
- Digital Engineering & Society 5.0

HUMAN-AI TEAMING

A HUMAN SYSTEMS INTEGRATION APPROACH

WHAT IS A SYSTEM?

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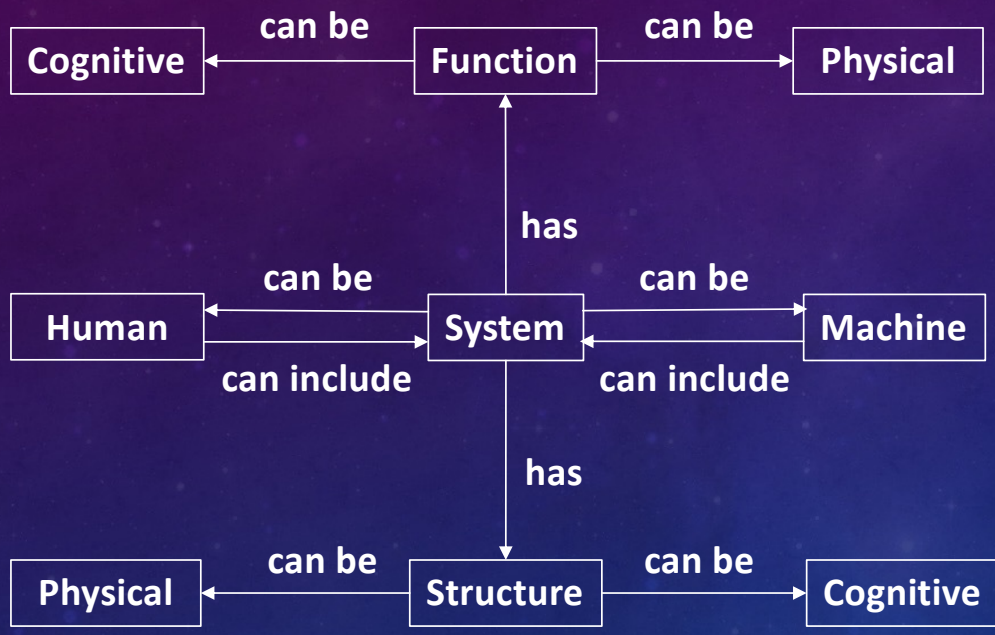
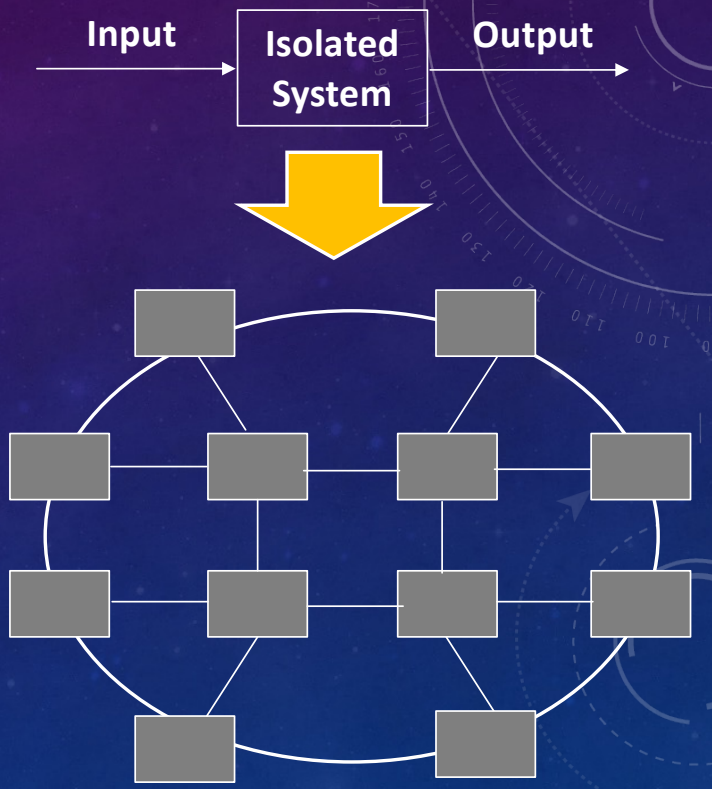


Systems include Humans and Machines…



Interconnected System of Systems

SYSTEM = STRUCTURE + FUNCTION

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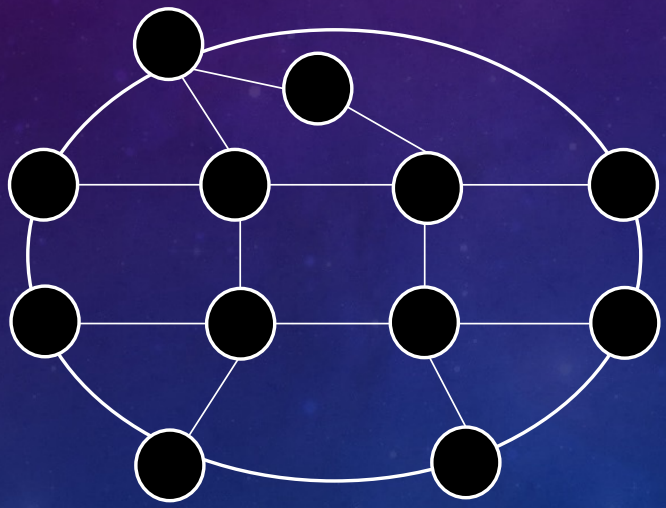
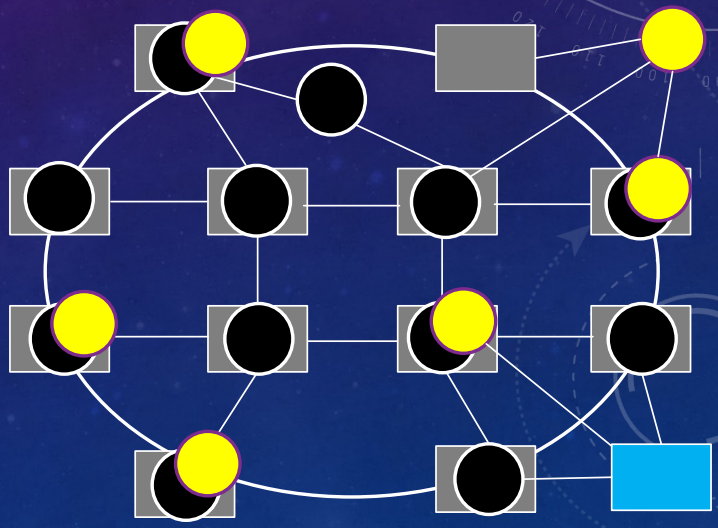


Interconnected Functions of Functions

Emergent Structures

Emergent Functions

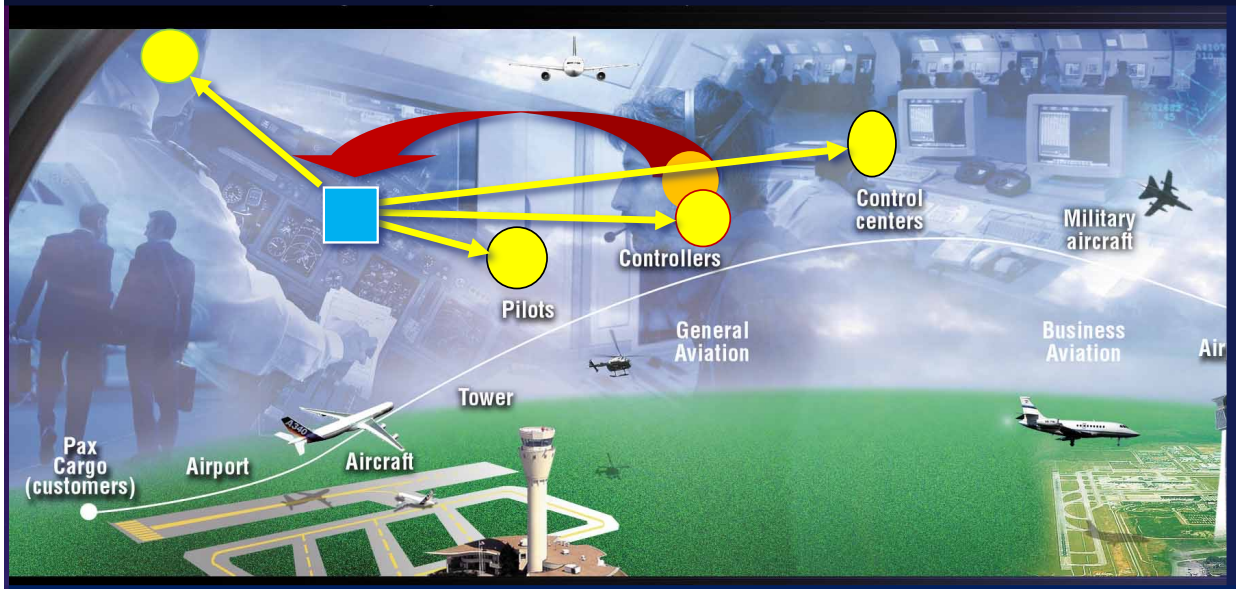
Overlapping Functions of Functions



Interconnected Structures of Structures

SYSTEM = STRUCTURE + FUNCTION

ATM SYSTEMS OF SYSTEMS



Machine cognitive function

Human cognitive function

PAUSA: Authority Sharing in the Air Space (2006-2008: France; 9 Partners)

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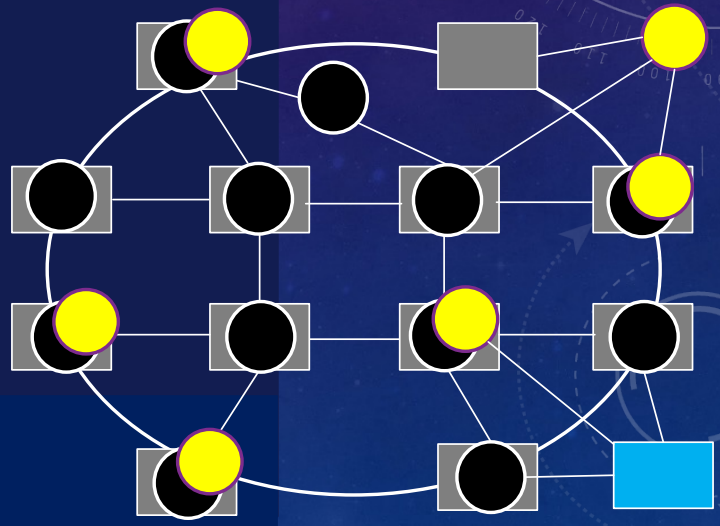
Emergent Structures

Emergent Functions

Overlapping Functions of Functions



Interconnected Structures of Structures

SYSTEMS OF SYSTEMS PROPERTIES

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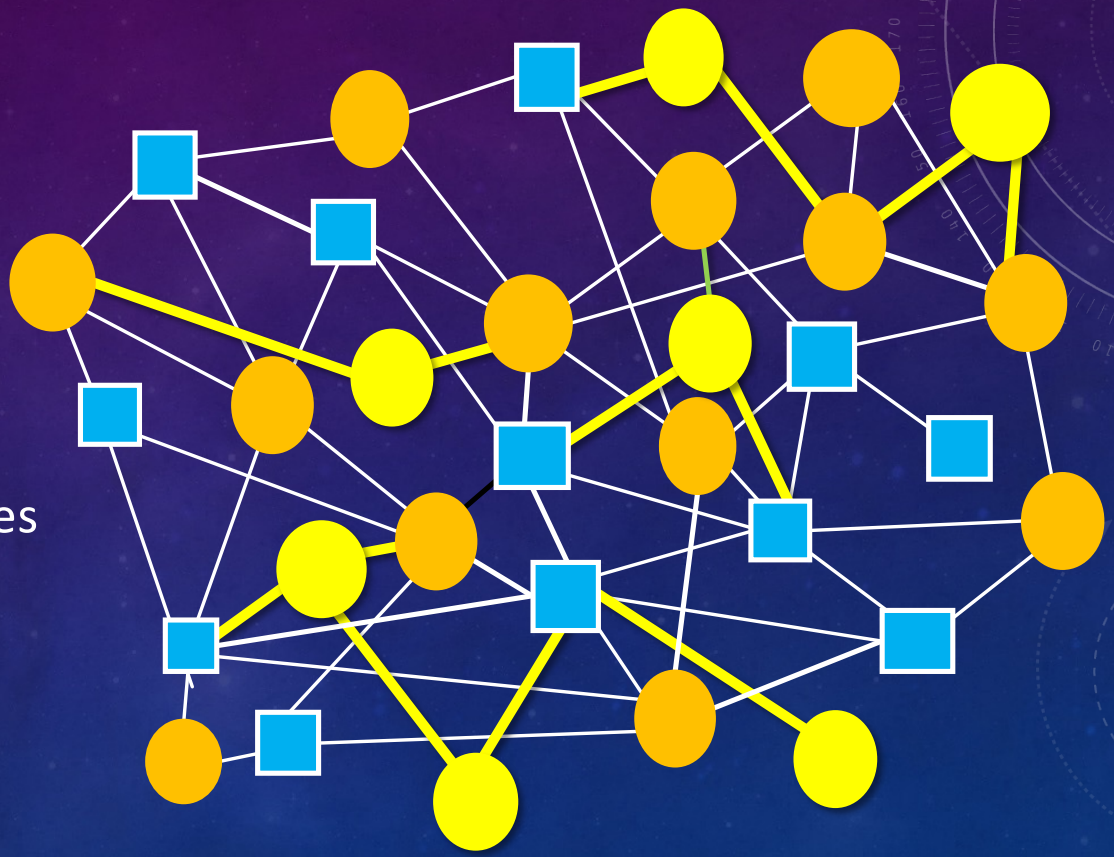
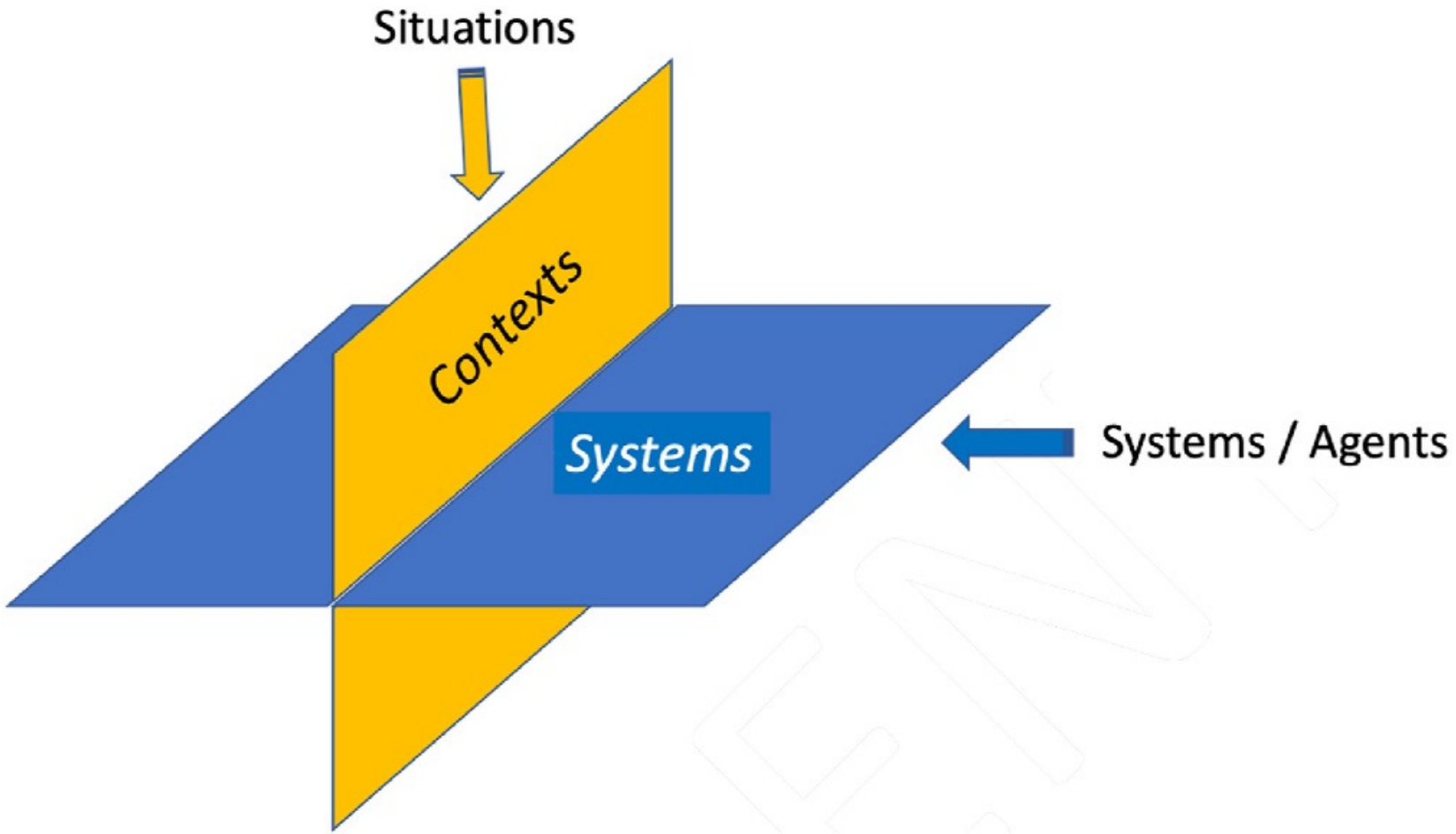
Separability
a crucial issue

Complexity
in connections
as well as
in agents/systems themselves

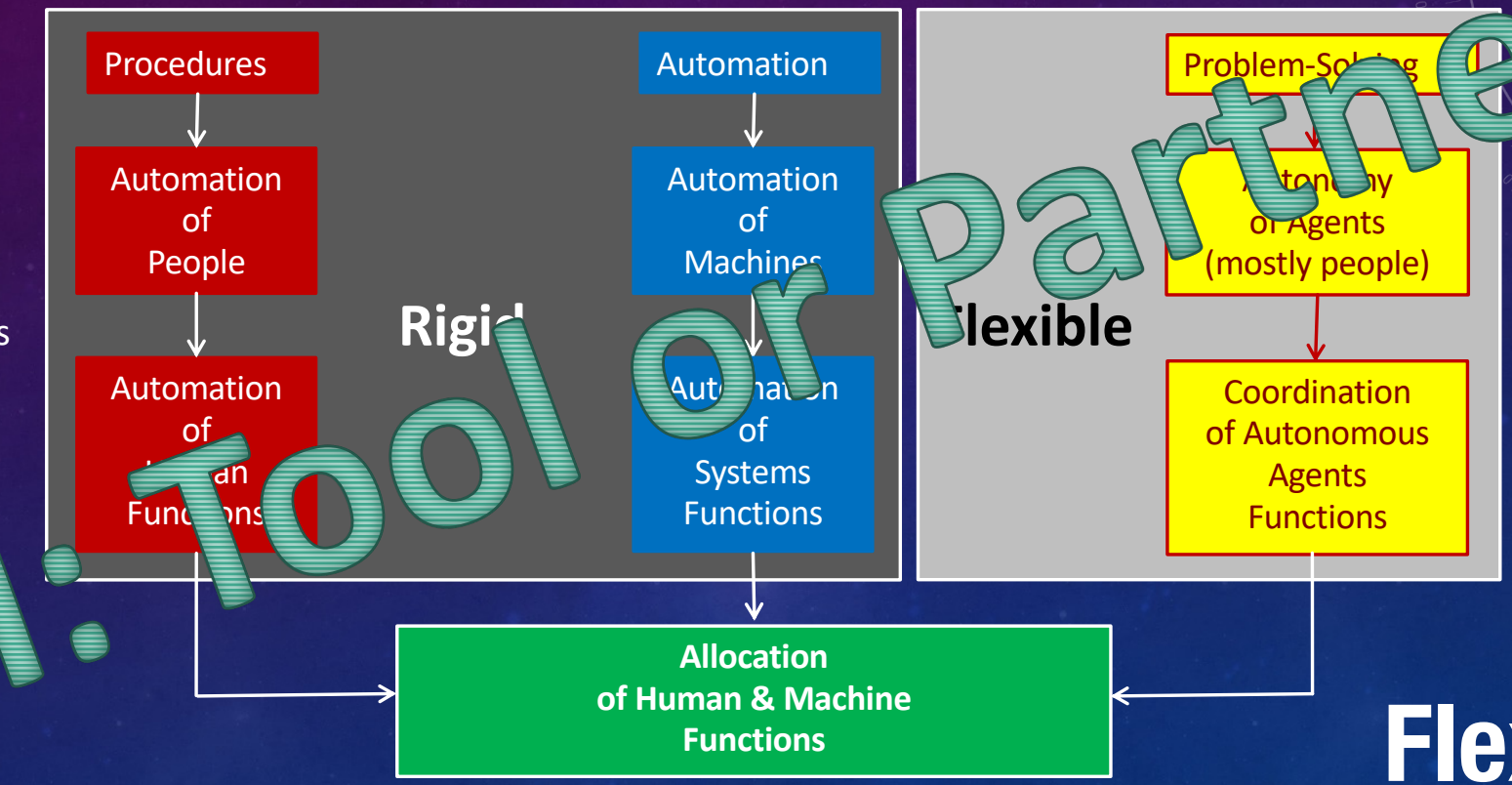
Emergent functions,
Coordination rules
and
the **maturity** issue



… therefore, this is a living organism


Situations
Contexts
Systems
Systems / Agents

FROM RIGID AUTOMATION TO FLEXIBLE AUTONOMY



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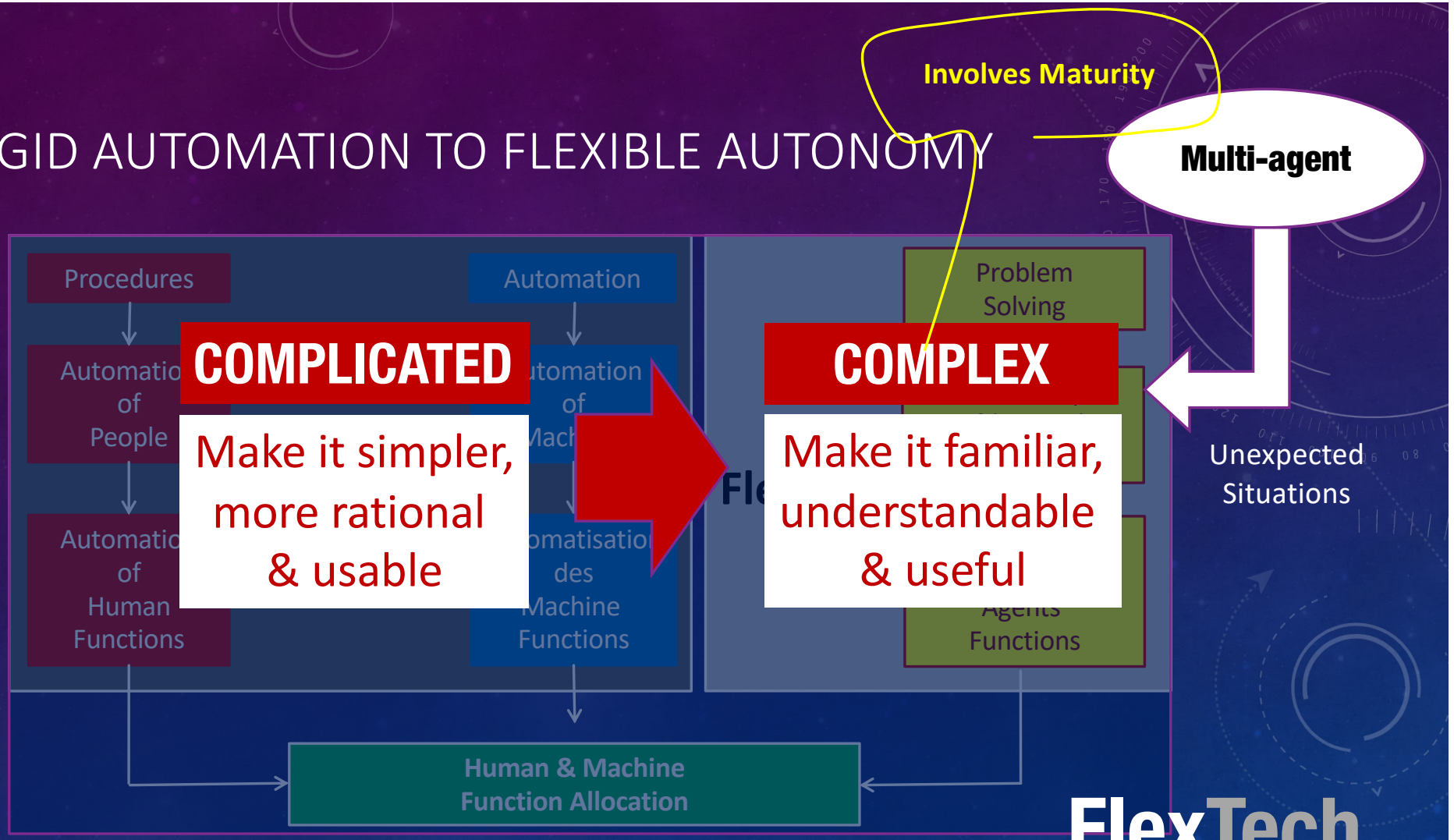
FROM RIGID AUTOMATION TO FLEXIBLE AUTONOMY



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

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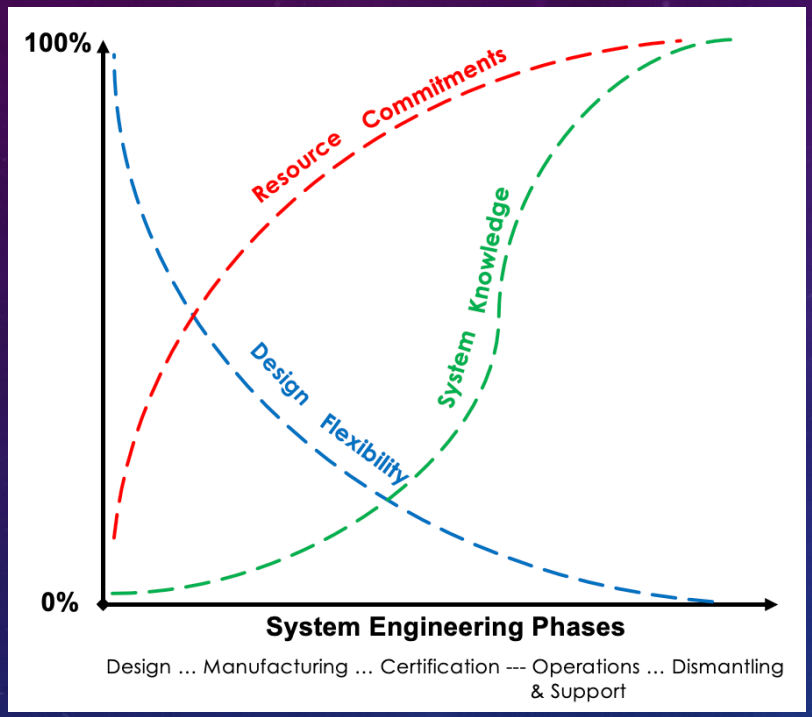
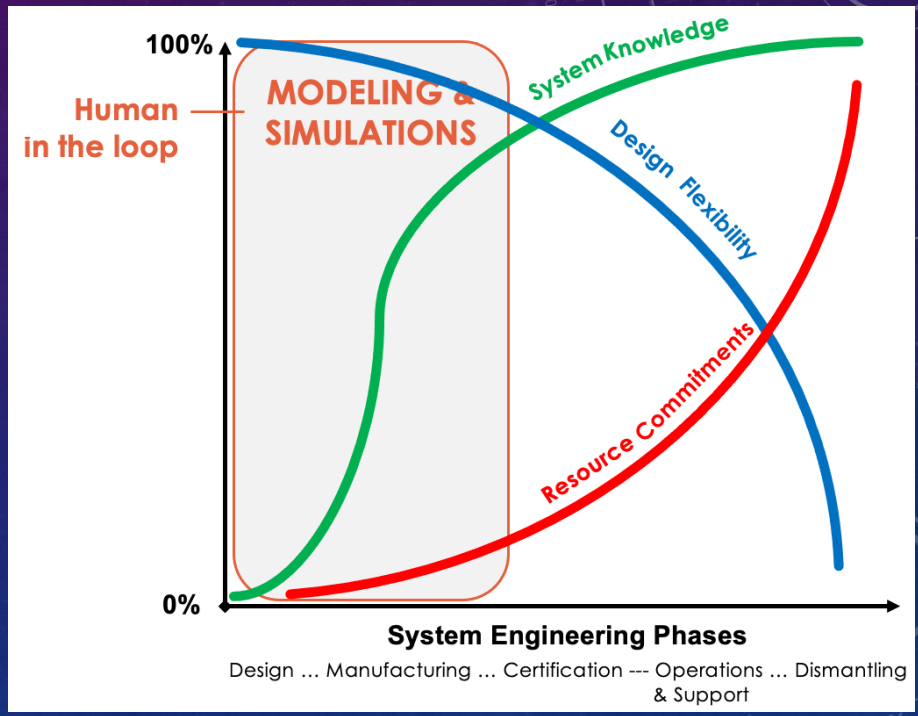
LIFE-CYCLED HUMAN SYSTEMS INTEGRATION…

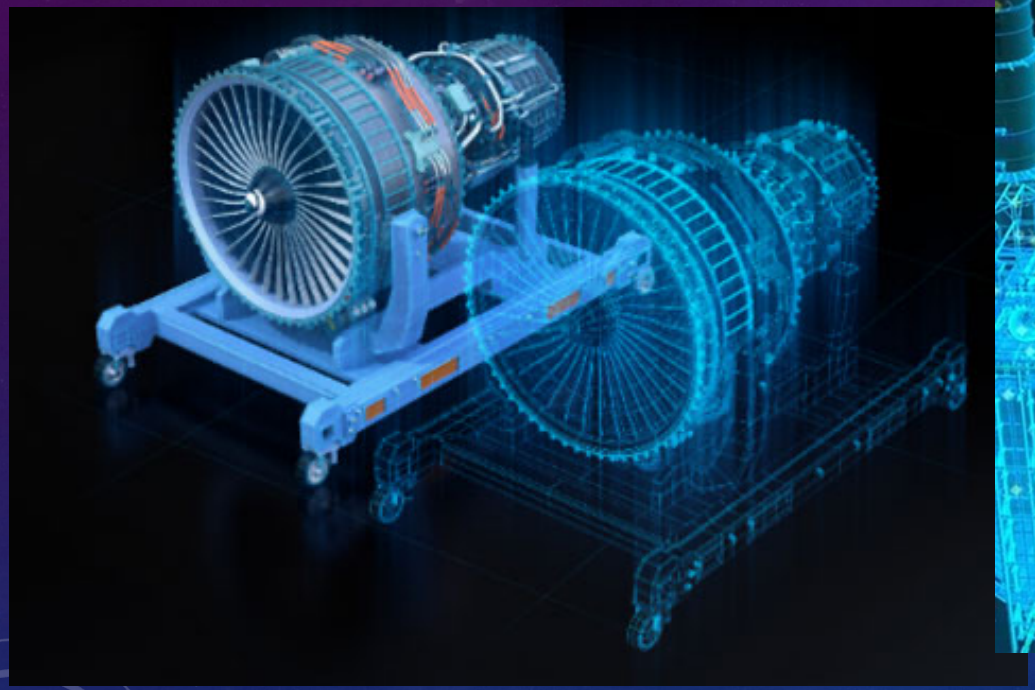
Technology-centered

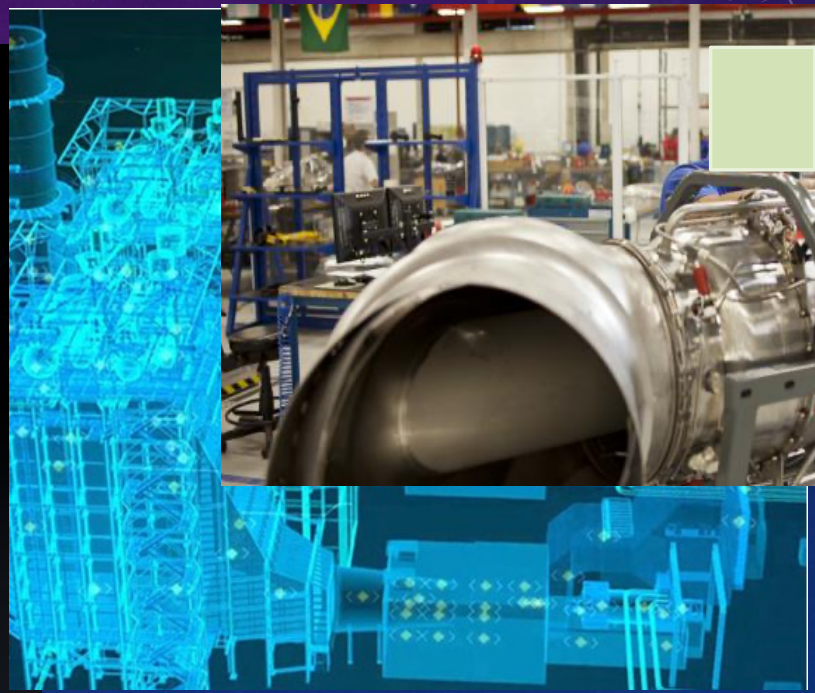


Human-centered



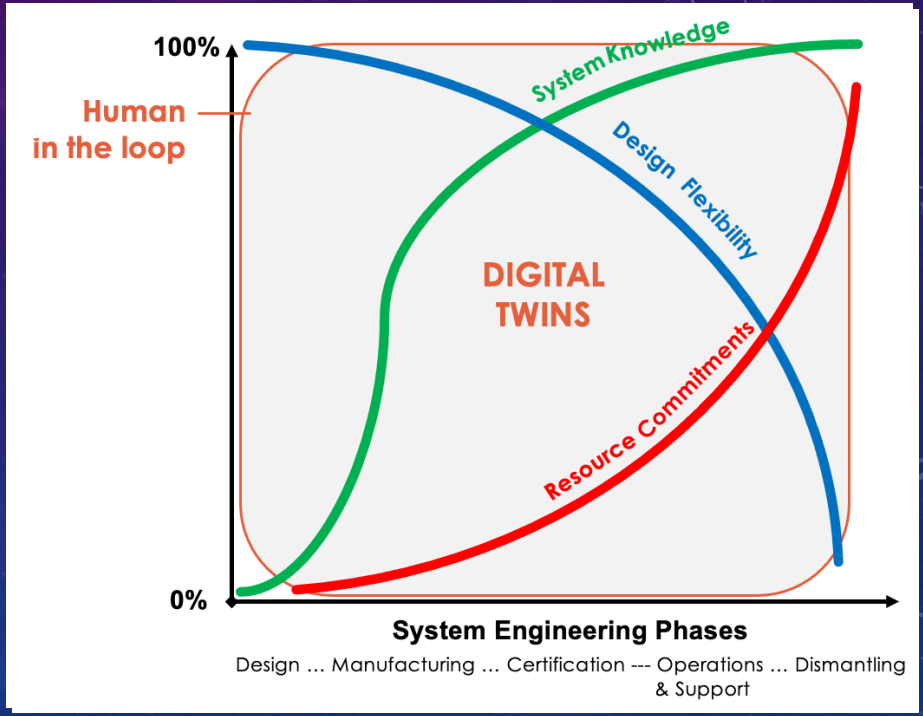
HUMAN-CENTERED DESIGN OF A DIGITAL TWIN FOR HELICOPTER ENGINE MAINTENANCE





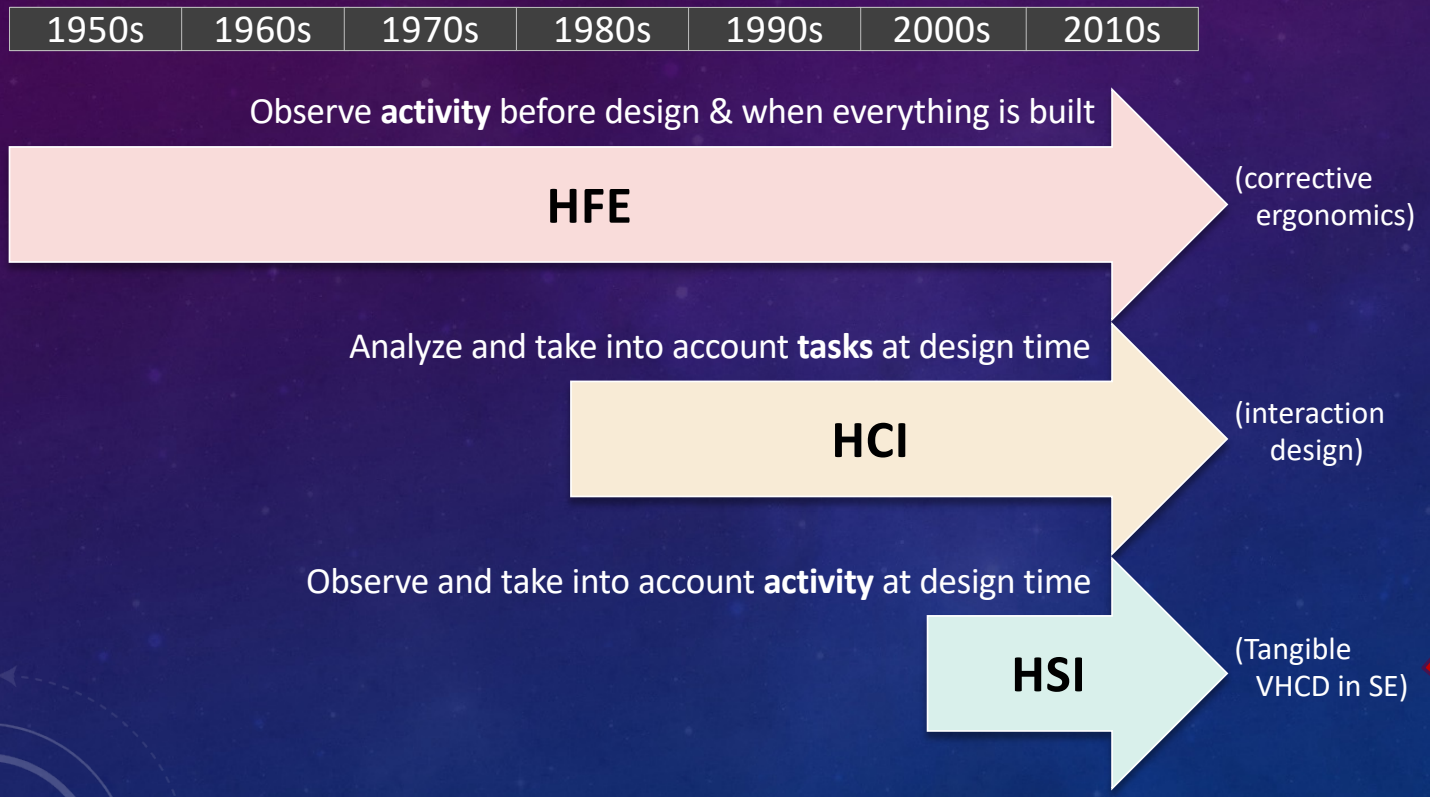
DIGITAL TWINS

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



TASK VS. ACTIVITY

Departing from the 20th Century User-Interface Syndrome…



Human Systems Integration…

HFE: Human Factors and Ergonomics
HCI: Human Computer Interaction
VHCD: Virtual Human-Centered Design
HSI: Human Systems Integration
SE: Systems Engineering

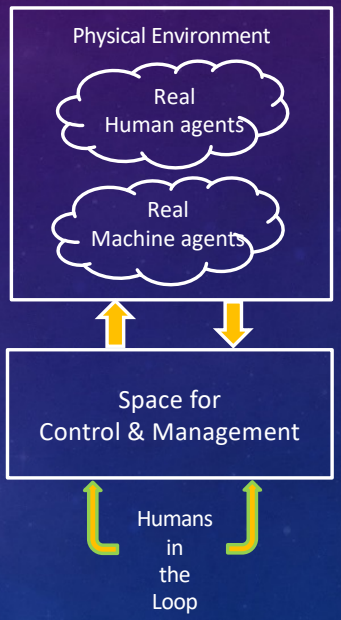
FROM MEANS TO PURPOSE

Engineering

Ergonomics
Automation

Factors
Human

Tangible
Traditional Engineering



Inside-out

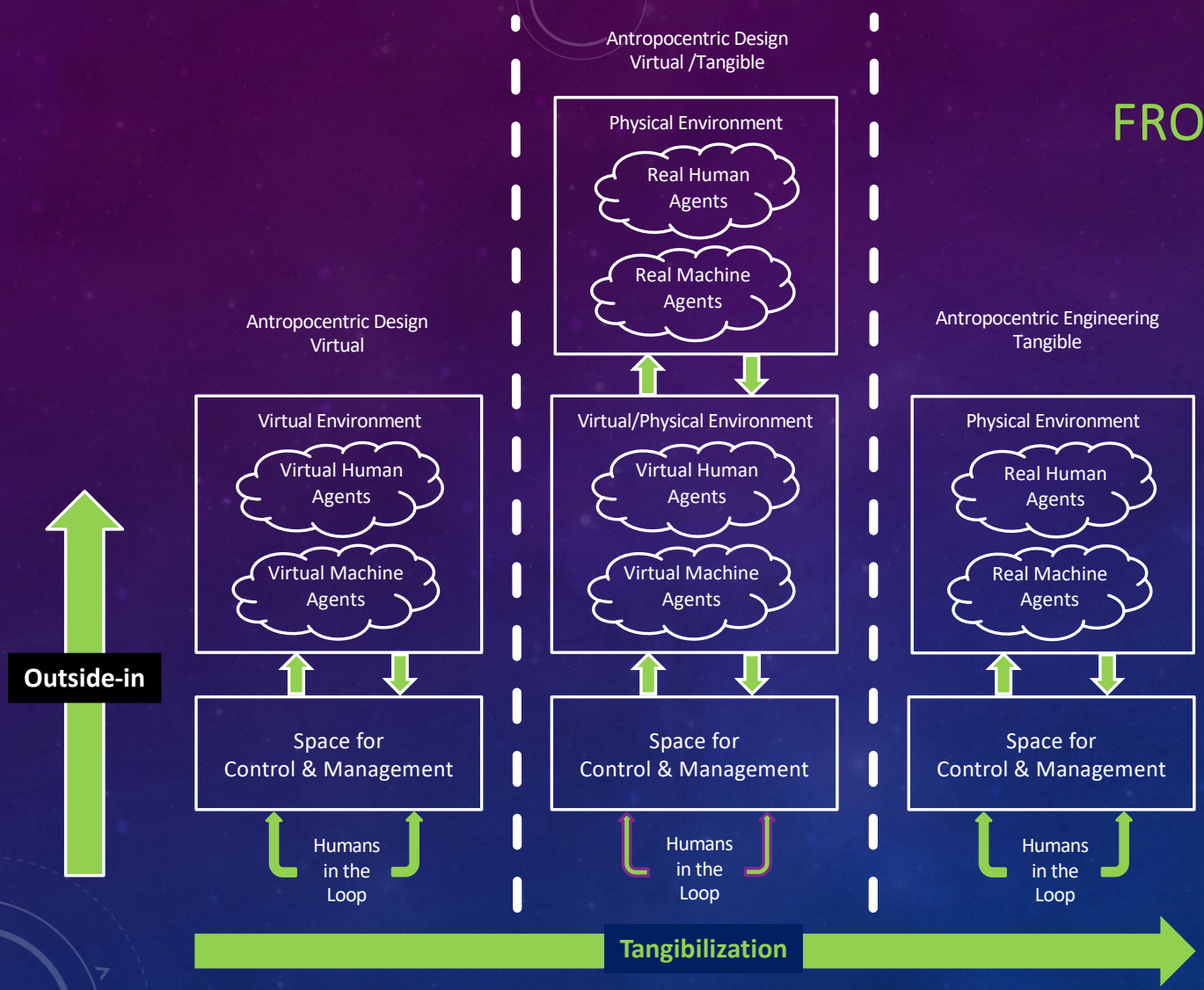
20TH CENTURY APPROACH

Engineering,
Ergonomics,
HCI &
Automation

FROM PURPOSE TO MEANS

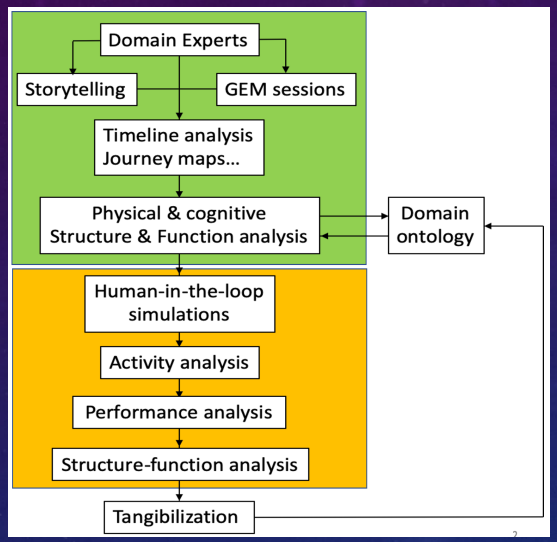
21ST CENTURY APPROACH

HSI



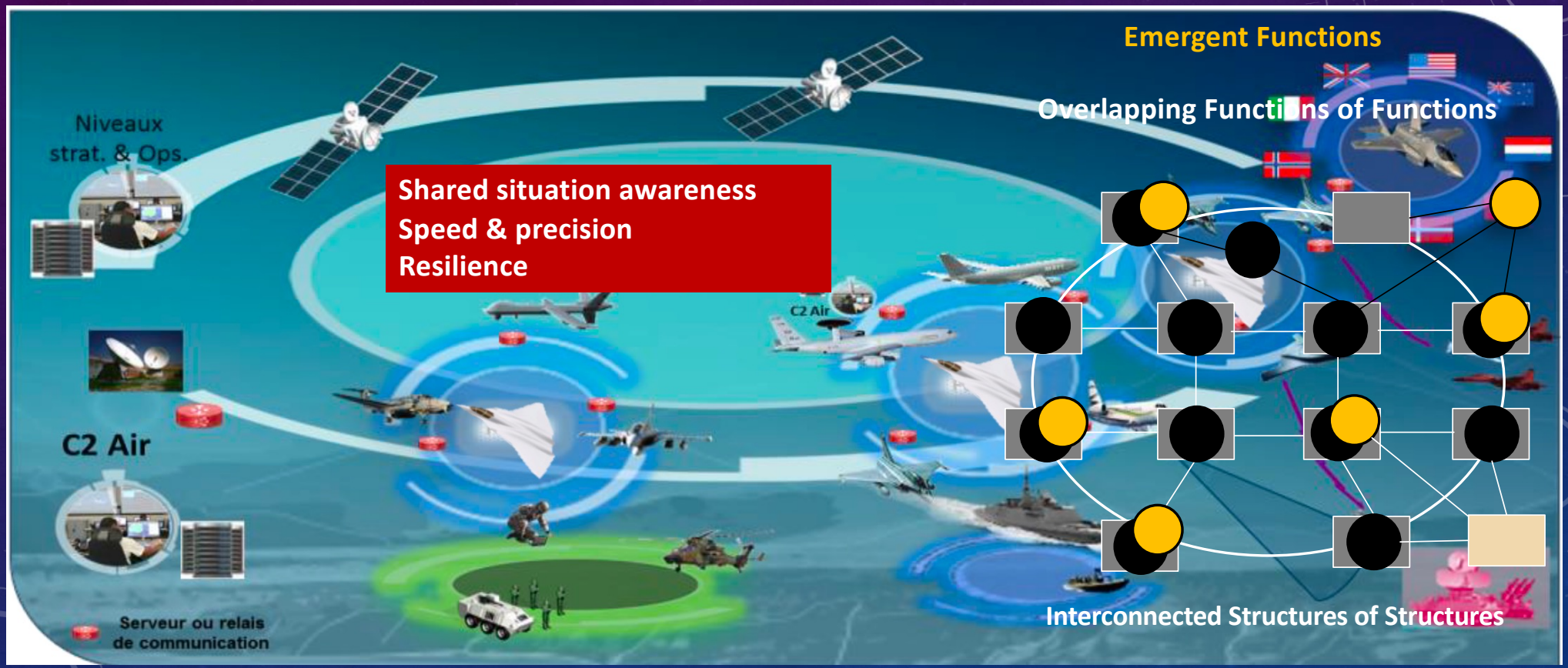
OFF-SHORE MULTI-AGENT TELEROBOTIC SYSTEMS

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



Tangibilisation

FUTURE COMBAT AIR SYSTEM (FCAS)

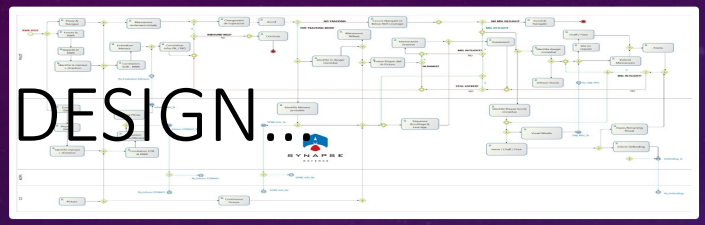


PRODEC

A method for the design, evaluation, operations, and support of increasingly digitalized complex sociotechnical systems

This is where Human-AI Teaming takes place!

SCENARIO-BASED DESIGN…



PRODEC

VIRTUAL PROTOTYPES…

Tangibility metrics

HUMAN-IN-THE-LOOP SIMULATION…

Activity analysis

Emergent function discovery

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

This book is a follow-up of previous contributions in Human-Centered Design and practice in the development of virtual prototypes that requires progressive operational tangibility toward Human-Systems Integration (HSI). The book discusses flexibility in design and operations, tangibility of software-intensive systems, virtual human-centered design, increasingly-autonomous complex systems, Human-Factors and Ergonomics of sociotechnical systems, and systems of systems integration.

This is an attempt to better formalize a systemic approach to HSI. Good HSI is a matter of maturity… it takes time to mature. It takes time for a human being to become autonomous, and then mature! HSI is a matter of human-machine teaming, where human-machine cooperation and coordination are crucial. We cannot think engineering design without considering people and organizations that go with it. We also cannot think new technology, new organizations and new jobs without considering change management, especially in digital organizations.

The book will be of interest to industry, academia, those involved with systems engineering, human factors and the broader public.

Features:

- Discusses flexibility in design and operations of complex systems
- Offers tangibility of software-intensive systems
- Presents virtual human-centered design
- Covers autonomous complex systems
- Provides human factors and ergonomics of sociotechnical systems

About the Author:

Guy André Boy is one of the pioneers and a world leader in the study and applications of human centered design and human systems integration. He is also the Chair of INCOSE Human Systems Integration Working Group worldwide.

Ergonomics and Human Factors

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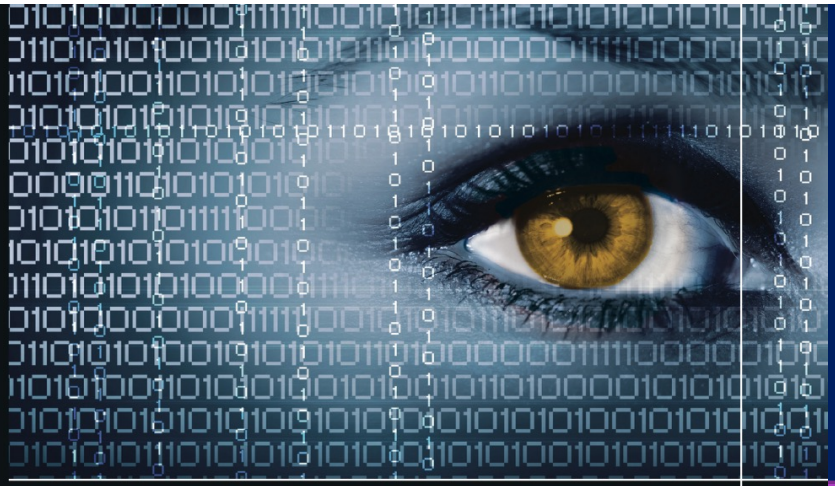
HUMAN-SYSTEMS INTEGRATION

Guy Andre Boy

CRC Press



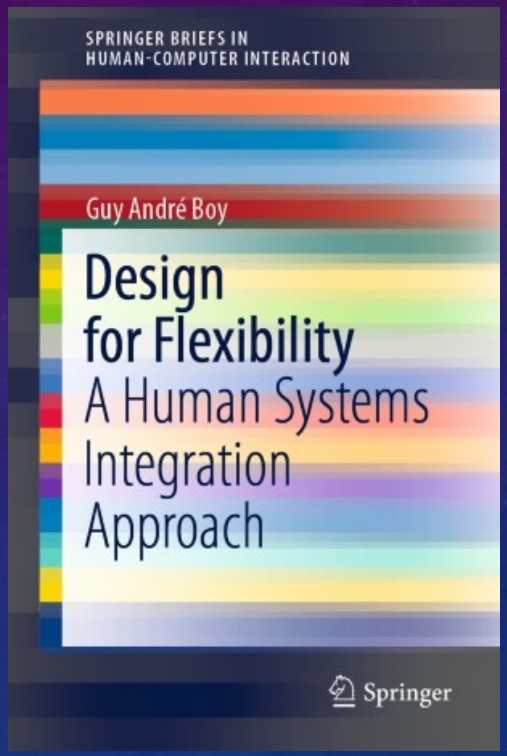
HUMAN-SYSTEMS INTEGRATION

From Virtual to Tangible

Guy Andre Boy

CRC Press
Taylor & Francis Group

… and another one!



HANDBOOK OF SOCIOTECHNICAL SYSTEMS

A HUMAN SYSTEMS INTEGRATION APPROACH

- To appear by the beginning of 2025
- About 50 chapters
- 16 countries

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.
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- Boy, G.A. (2020). *Human Systems Integration: From Virtual to Tangible*. CRC Press – Taylor & Francis Group, USA (https://www.taylorfrancis.com/books/9780429351686).

THIS SPRING SCHOOL…

- AI4SE & SE4AI – Dr. Tom McDermott, SERC, USA
- HAT Support – Dr. Mica Endsley, SA Technologies, USA
- Organizational Issues in HAT – Prof. Gudela Grote, ETH, Switzerland
- HAT & Safety – Prof. Philippe Palanque, IRIT-FlexTech, France
- HAT Design & Creativity – Dr. Dr. Norbert Streitz, Smart Future Initiative, Germany
- HAT is Space Exploration – Dr. So young Kim, JPL-NASA, USA

4 USE-CASES → 4 GROUPS

Will use PRODEC supported by IngeScape

1. Wednesday: Problem statement
2. Thursday: Problem-solving
3. Friday: Reporting and discussion

- **Group 1: Remote Virtual Tower – Alexandre Disdier & Justine Limoges**
- **Group 2: Oil & Gas Robotics – Dimitri Masson, Élise Durnerin & Stéphane Vales**
- **Group 3: Rail Automation – Yang Sun & Madeline Fleury**
- **Group 4: Air Combat System – Chloé Morel, Laurent Goumy & Charlotte Strobbe**

USE-CASE GROUPS

Group 1	Group 2	Group 3	Group 4
Tilo Mentler	Elise Durnerin	Aurélie Akli	Frank Flemisch
Fabrice Drogoul	Ronald Herrera	Kahina Amokrane	Françoise Darses
Jean-Baptiste Ado-Solaberrieta	Brittany Lock	Allan Armougum	Dr. Mica Endsley
Dr. Tom McDermott	Roberto Martinez	Afef Awadid	Laurent Goumy
Milad Leiyli-Abadi	Dimitri Masson	Prof. Gudela Grote	Yanrong Huang
Justine Limoges	Jean-Michel Munoz	Madeline Fleury	Sathyanarayanan Raman
Edzer Oosterhof	Stéphane Vales	Dr.Dr. Norbert Streitz	Chloé Morel
Ricardo Rais	Dr. KIM So Young	Yang Sun	Tanya Paul
Benjamin Berton	Chaoran Zhang		Charlotte Strobbe
Sandra Steere			Léonore Bourgeon

THANK YOU FOR YOUR ATTENTION!

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Future Integrated Automation in Aviation

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