



# PEOPLE'S ROLE IN LARGE INTERCONNECTED SYSTEMS

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**FlexTech**

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# OUTLINE

- Complex systems
- Systems as representations... toward a human and machine systemic modeling language
- Task vs. activity
- The evolution of human factors & ergonomics
- Defining Human Systems Integration (HSI)
- PRODEC: operations-centered design toward HSI

# INTERPENETRATION OF AUTOMATED SYSTEMS...

## ... BETWEEN AIR AND GROUND

- Large programs, e.g., NextGen & SESAR, in accordance with a **roadmap** (described in ASBU) of ICAO
- A first onboard implementation resulting from this work consists of exchanging the **aircraft's 4D trajectory** with ATC and AOC on departure and periodically in flight
- Another solution is based on concepts of **separation** between aircraft (ASAS based on ADS-B capabilities) which has the advantage over the previous solution of allowing separation between aircraft in a “relative” way (in terms of time difference) and not in an “absolute” way (in absolute time) which is more difficult to obtain given the hazards (delay and time variations of other aircraft...)

ASBU: Aviation System Block Upgrade  
ASAS: Airborne Separance Assurance System  
ADS-B: Automatic Dependent Surveillance-Broadcast  
AOC: Aeronautical operational control  
ATC: Air Traffic Control  
NextGen: Next Generation Air Transportation System  
SESAR: Single European Sky ATM Research

# OUTLINE

- Human System Integration (**HSI**)
- Orchestrating Technology, Organization and People (the **TOP Model**)
- **FlexTech**... flexible Socio-Technical Systems (STS)
- Anticipation, preparation, creativity and experience
- From rigid automation to flexible autonomy
- Dealing with the **unexpected**
- Human-Centered Design of STS as complex life-critical systems
- Well-being, safety, sustainability and efficiency
- Put the artificial at the service of the natural, and not the other way around

# MY WORLD FOR ~40 YEARS...



From correction...  
... to interaction  
... to integration

... and other things

# HUMAN-CENTERED DESIGN (HCD)

## HCD for whom?

- Pilots, controllers, maintenance personnel, airlines, etc.
- Engineering designers, developers, manufacturers, certifiers, etc.

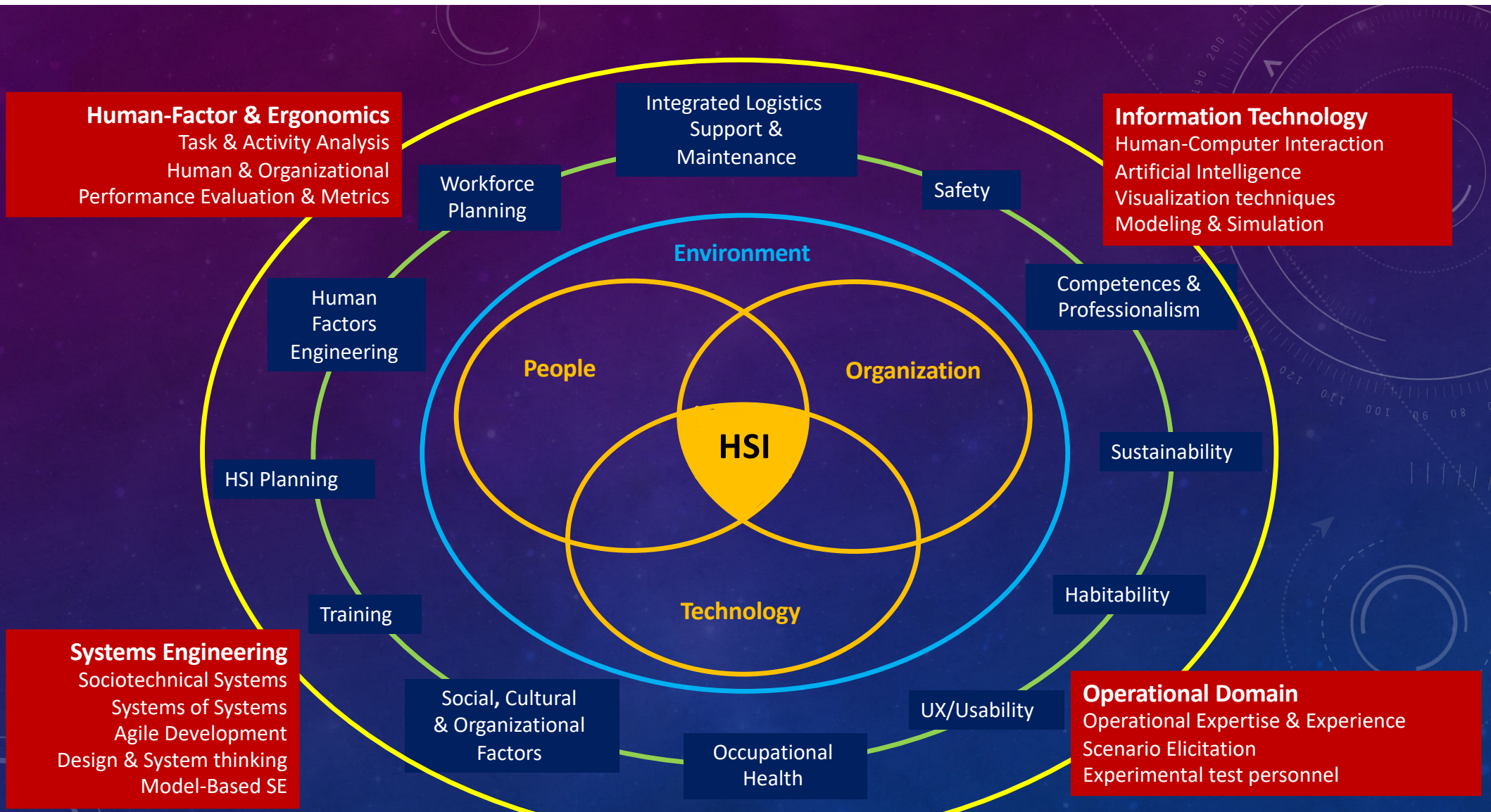
HCD assumes that there is always the **human element** everywhere

- How do we consider the human element?
- What are the theoretical and practical methods and tools?

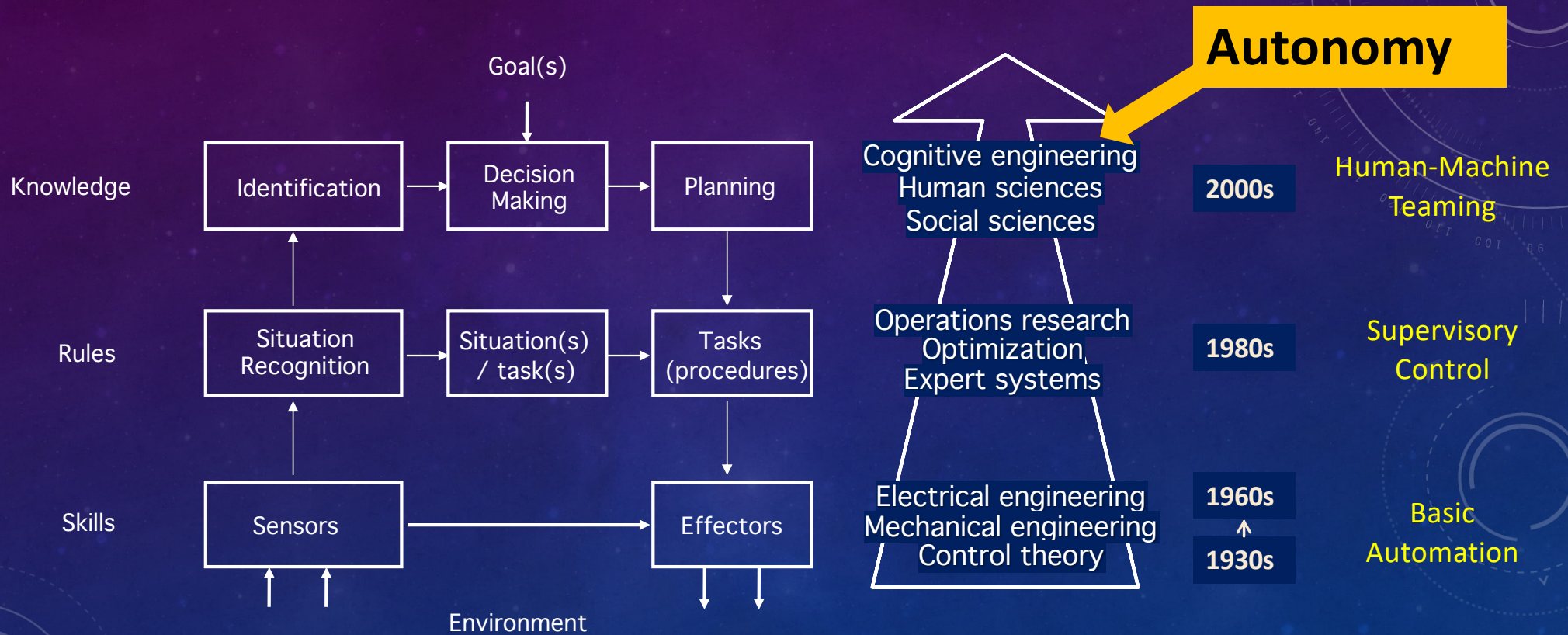
HCD of sociotechnical systems in a **digital world**

- Co-designing Technology, **Organization** and People's activities (TOP Model)
- Think about the **life cycle of systems**





# FROM AUTOMATION TO AUTONOMY... ... and emergence of contributing disciplines (Rasmussen's model)



Boy, G.A. & Morel, C. (2022 to appear). The Machine as a Partner: Human-Machine Teaming Design using the PRODEC Method. WORK Journal.



# TASK VS. ACTIVITY

1950s

1960s

1970s

1980s

1990s

2000s

2010s

Observe **activity** before design & when everything is built

**HFE**

(corrective ergonomics)

Analyze and take into account **tasks** at design time

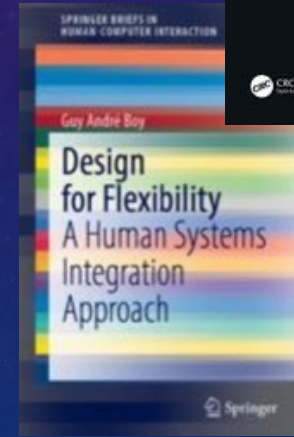
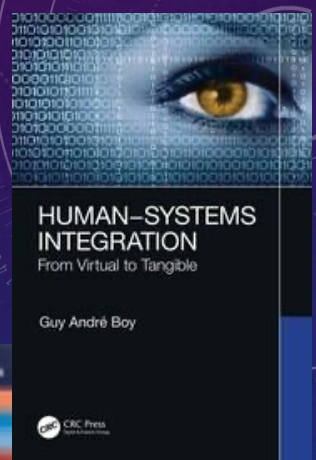
**HCI**

(interaction design)

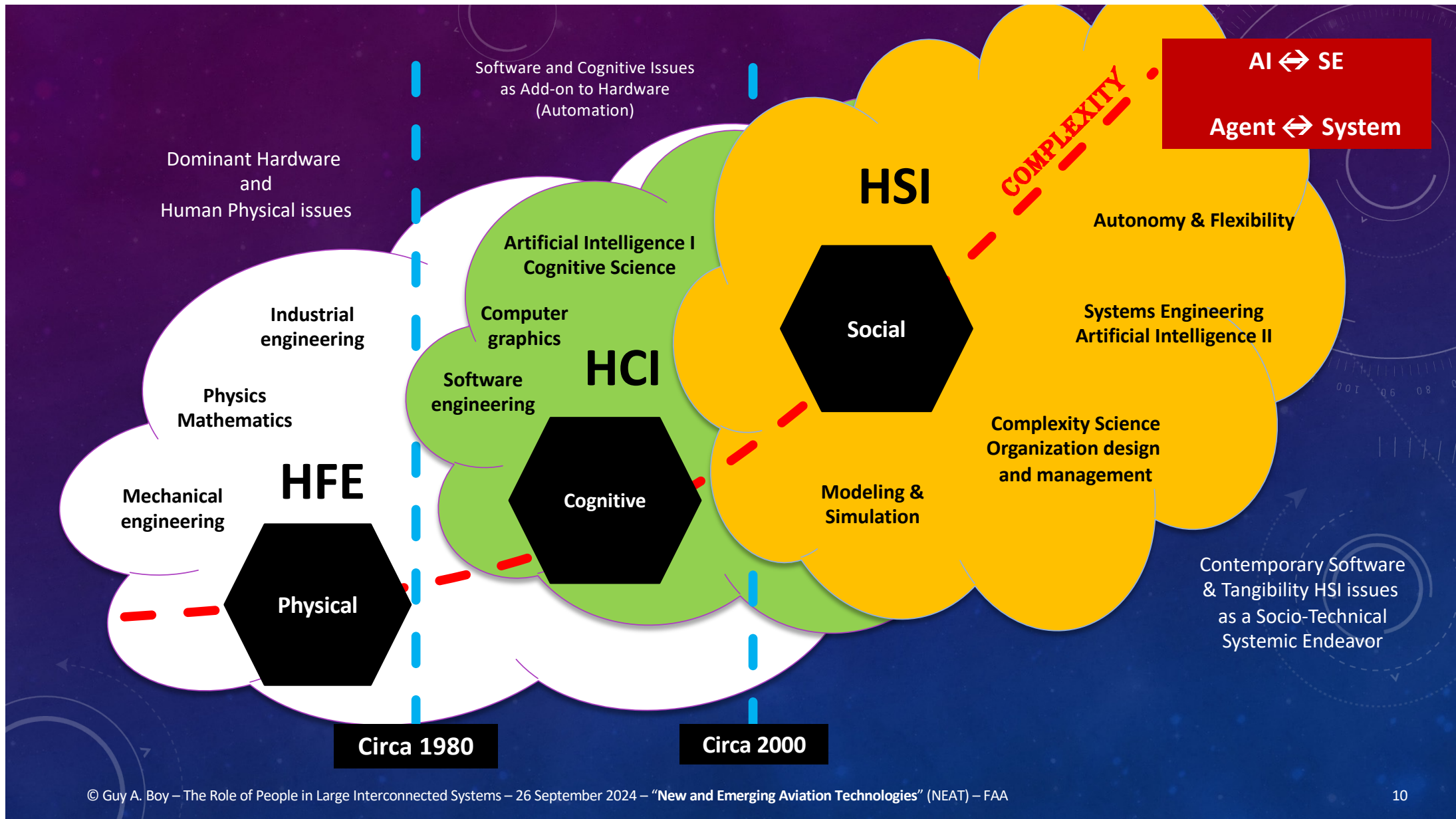
Observe and take into account **activity** at design time

**HSI**

(Tangible VHCD in SE)



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



**COMPLEX**



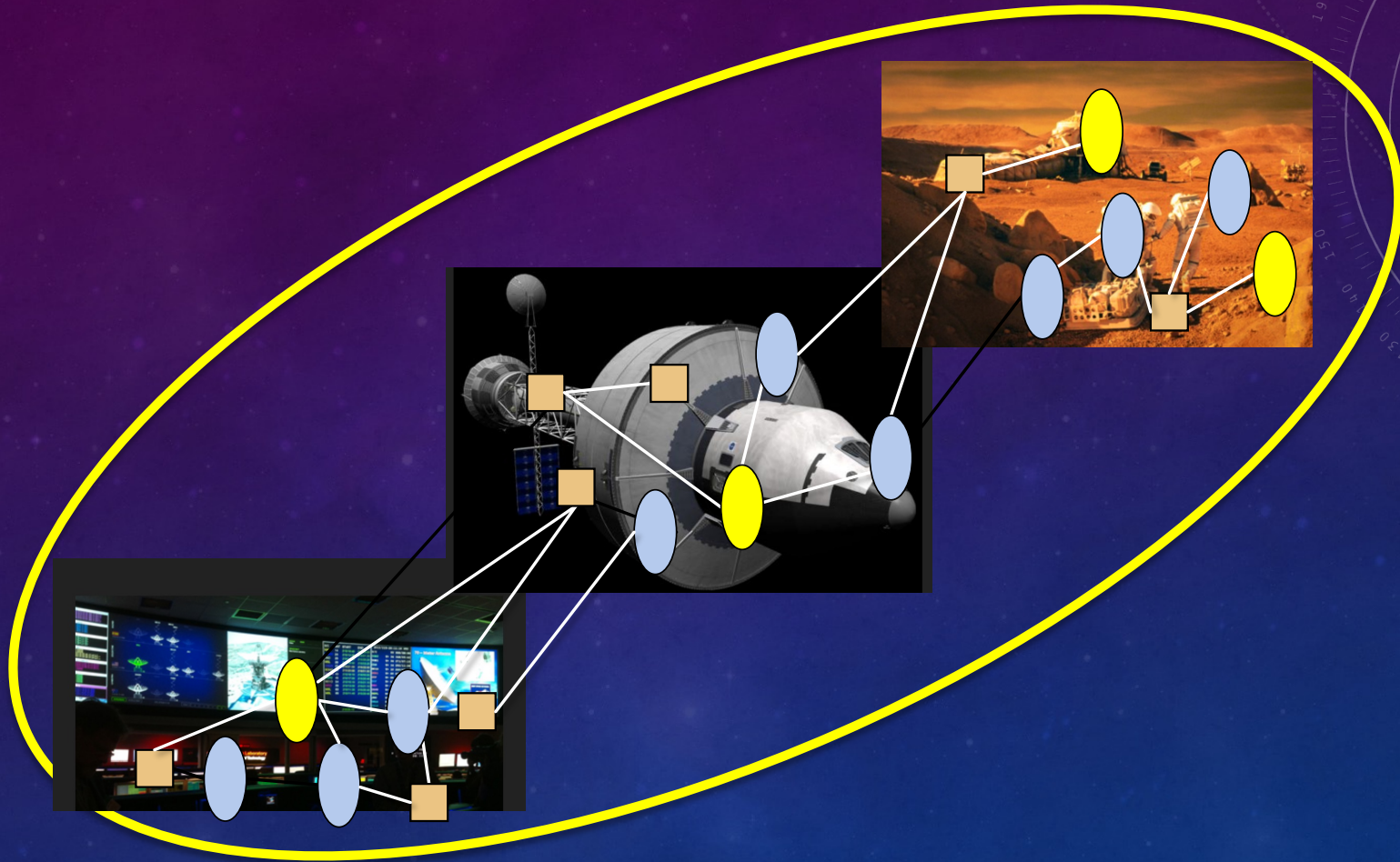
**COMPLICATED**

Make it **familiar**,  
understandable,  
and usable

Make it **simpler**,  
more rational,  
and useful

## THE COMPLEX-COMPLICATED DISTINCTION

# DEALING WITH COMPLEXITY

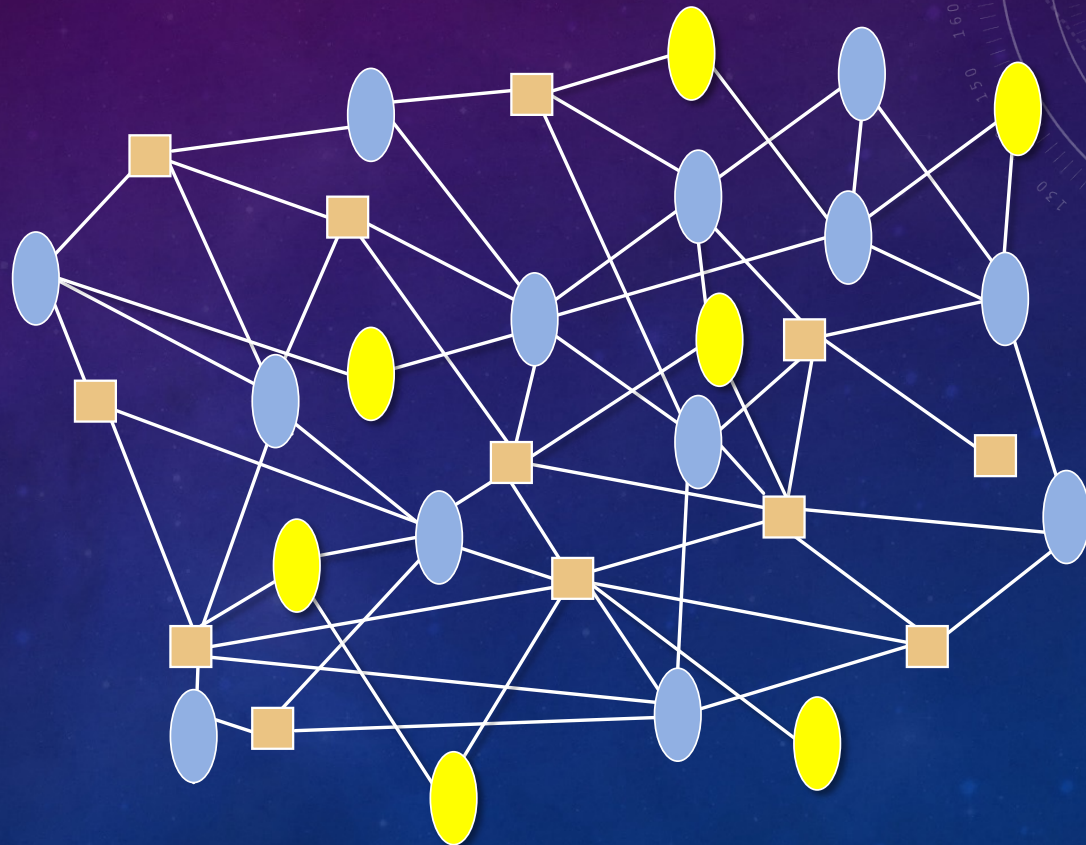


# A COMPLEX SYSTEM AS A LIVING ORGANISM

**Separability**  
a crucial issue

**Complexity**  
in the connexions  
as well as  
in the agents themselves

**Emergents Functions**  
&  
the **maturity** issue



# PROPERTIES OF A COMPLEX SYSTEM

- a large **number** of components and interconnections among them
- many people involved in its **life cycle**  
(design, development, manufacturing, operations, maintenance and dismantling)
- **emergent** properties and behaviors not included in the components
- complex adaptive mechanisms and behaviors (**adaptability**)
- nonlinearities and possible chaos (**unpredictability**)

# METHODS & TOOLS

- Design thinking: creativity & ideation
- Task analysis & Scenario-based design
- Conceptual modeling
- **PRODEC**
- Rapid prototyping
- Human-in-the-loop simulation
- Evaluation methods and tools
- Agile development
- Organizational design & management



INTEGRATION



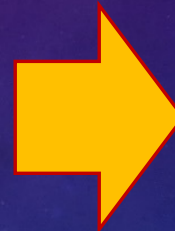
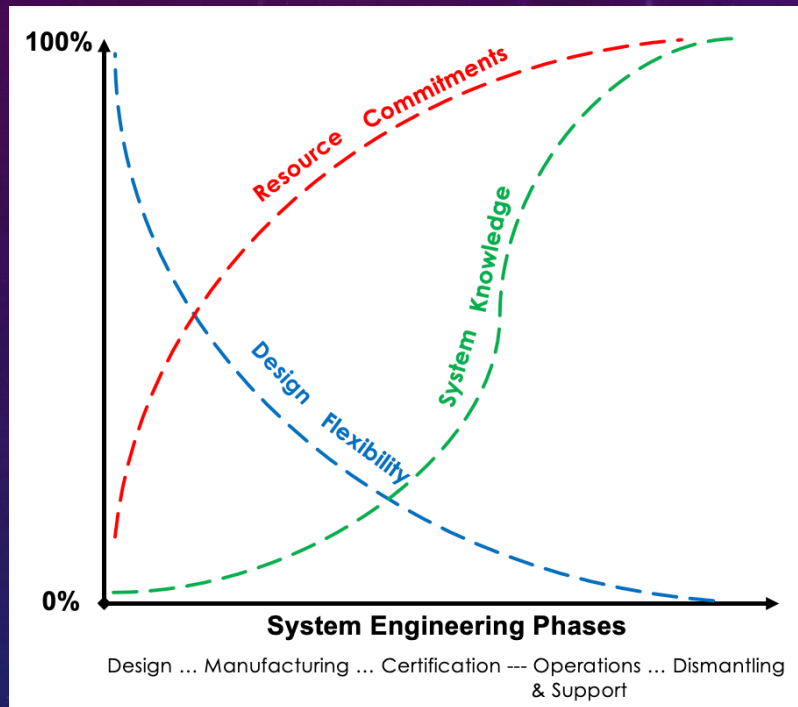
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# INTEGRATION

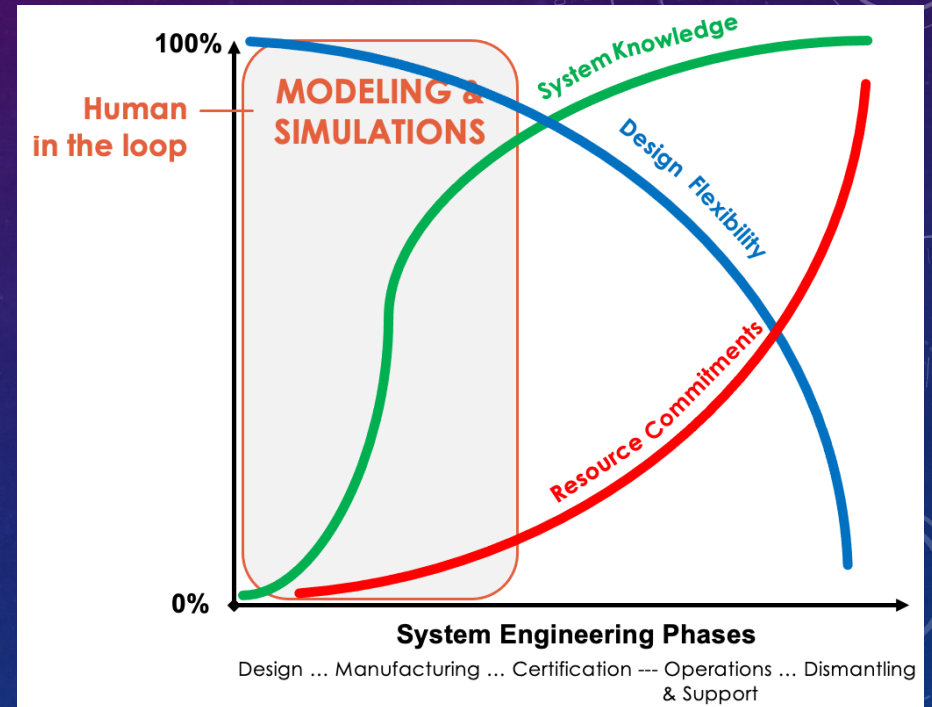
## FROM THE EARLY STAGES OF DESIGN

# LIFE-CYCLED HUMAN SYSTEMS INTEGRATION

Technology-centered



Human-centered

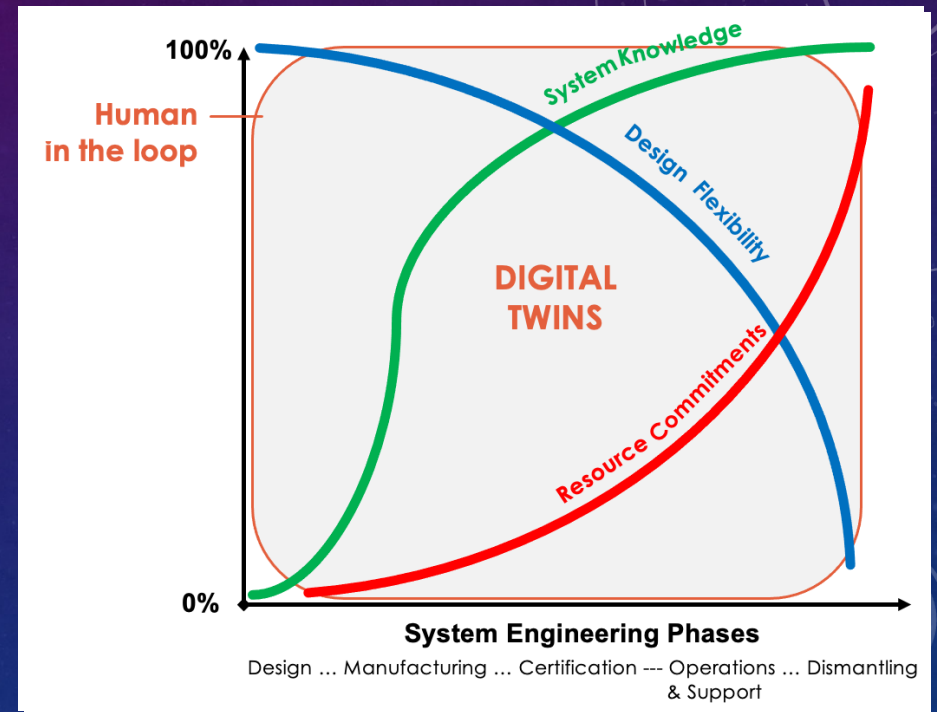


# HUMAN-CENTERED DESIGN OF A DIGITAL TWIN FOR HELICOPTER ENGINE MAINTENANCE

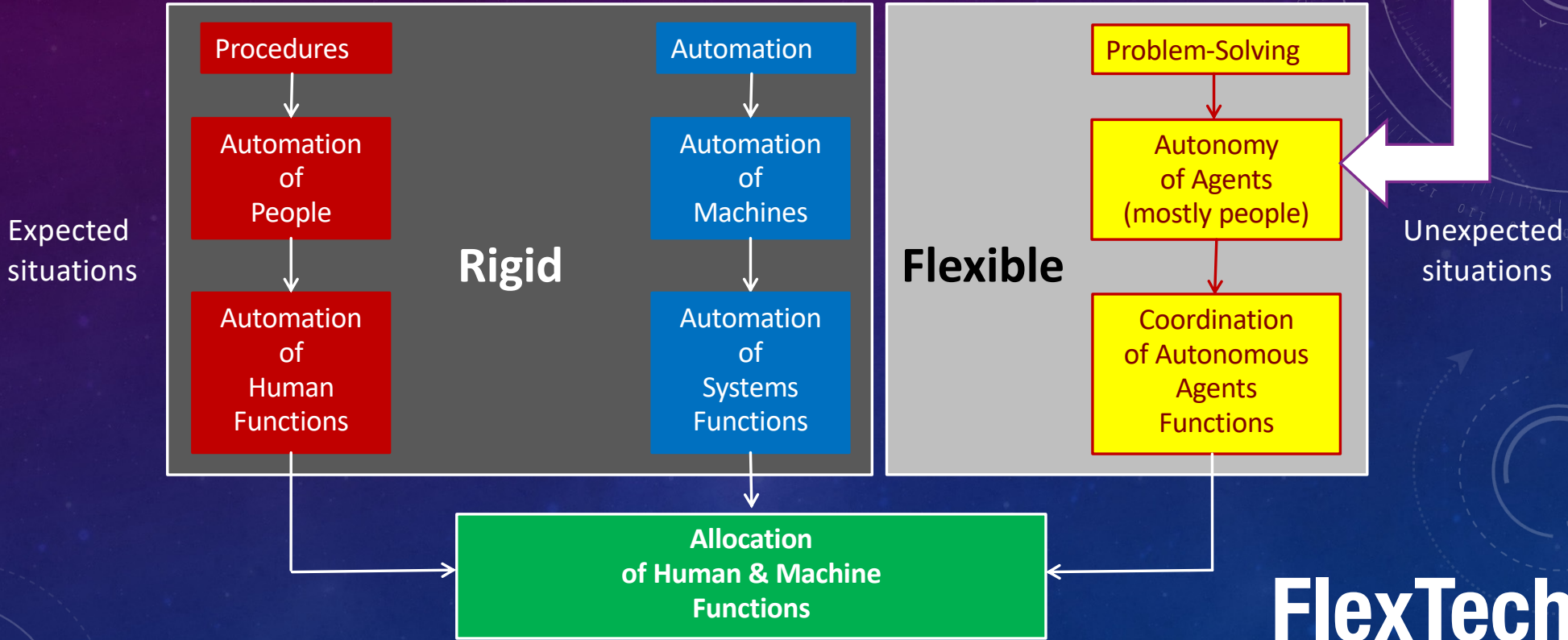


# DIGITAL TWINS

- Expanding HITLS
  - During the whole life cycle
  - “what if?”
- Vivid documentation
  - Integration of experience feedback
  - Organizational memory
- Digital twins as virtual assistants
  - Multi-agent collaboration
  - Mediators for collaborative work



# FROM RIGID AUTOMATION TO FLEXIBLE AUTONOMY



# FlexTech

CentraleSupélec-ESTIA Chair

**HSI**

HUMAN SYSTEMS INTEGRATION

=

**HCD**

HUMAN-CENTERED DESIGN

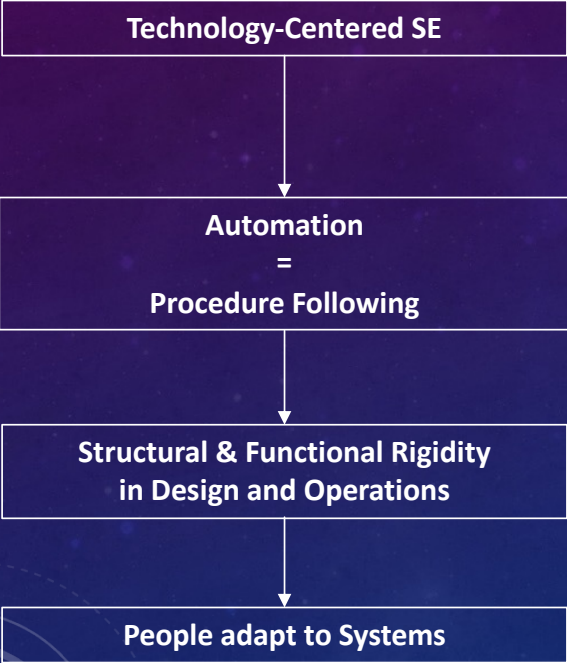
+

**SE**

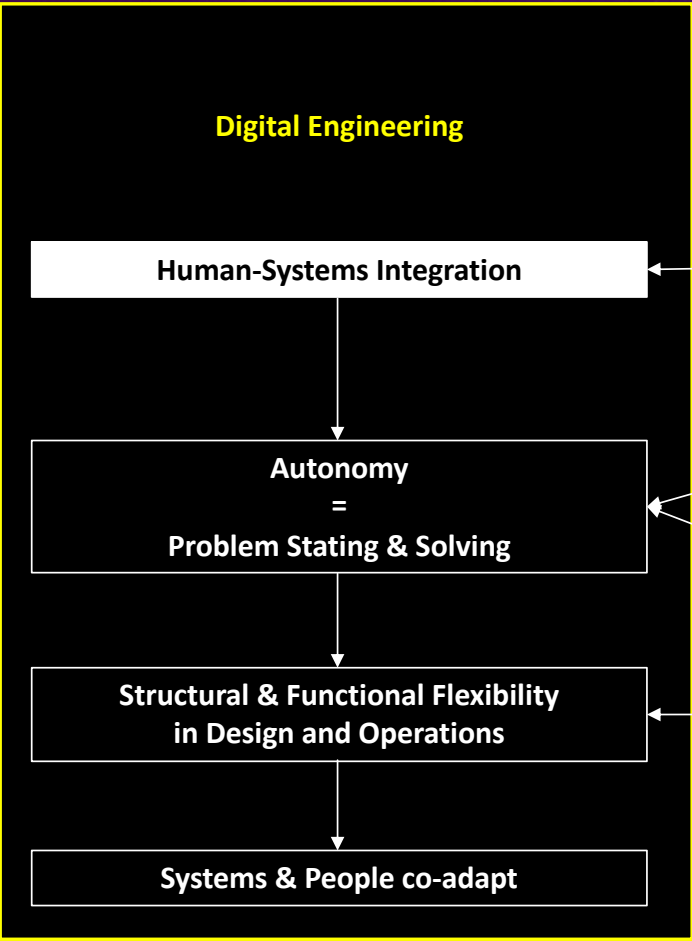
SYSTEMS ENGINEERING

# Toward more Autonomy & Flexibility

## Traditional Engineering



## Digital Engineering



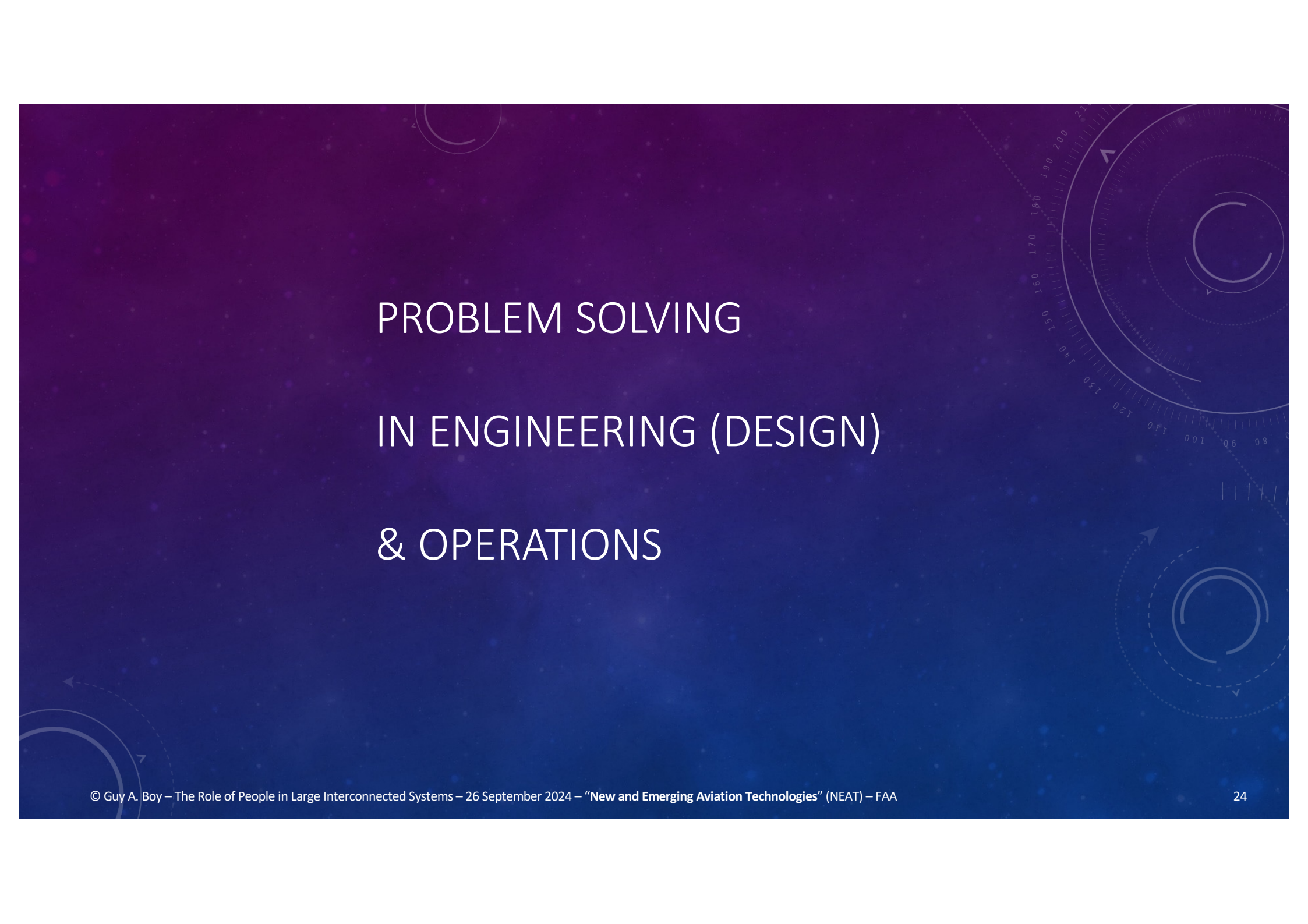
Human-Centered Design (HCD) combined with Systems Engineering (SE) contributes to improving Human-Systems Integration (HSI)

Human Factors, Modeling & Human-In-The-Loop Simulation

Data Science & Artificial Intelligence

Creativity, Complexity Analysis, Agility, Tangibility, Maturity

... HSI

The background features a dark blue gradient with a starry space pattern. On the right side, there are several technical diagrams, including a large circular gauge with numerical markings from 0 to 210 and a smaller circular diagram below it. The text is centered in white, sans-serif font.

# PROBLEM SOLVING IN ENGINEERING (DESIGN) & OPERATIONS



# FLEXTECH

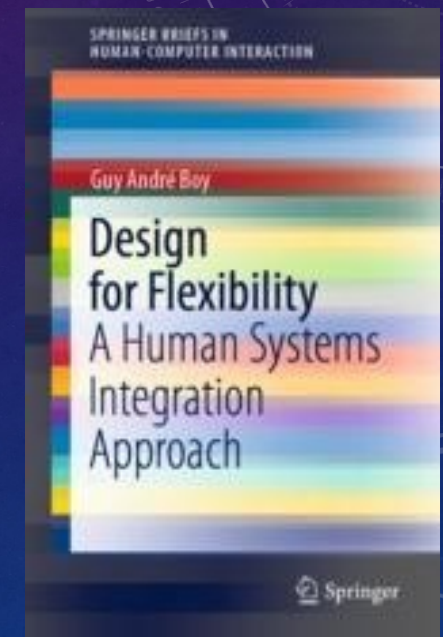
Design for Flexibility

What kind of support?

technology

organization

competence

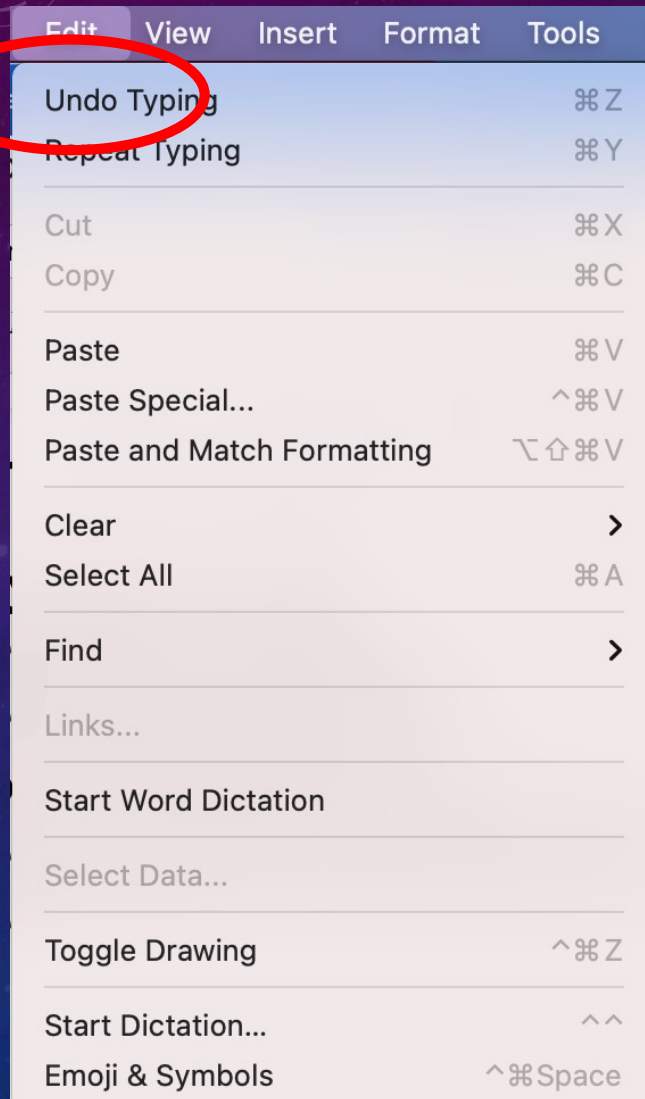


<https://www.springer.com/gp/book/9783030763909>

# FLEXTECH

Design for Flexibility

Technological support



# APOLLO 13 CO<sub>2</sub> ...



Design for Flexibility

Organizational support

## ... collaborative problem solving!

# FLEXTECH

## Creativity & Experience



# FLEXTECH

People

**Human  
Centered  
Design  
& Operations**

Technology

Organizations

## Technology

- Problem-solving tool support
- e.g., undo

## Organization

- Problem-solving team
- E.g., Apollo 13

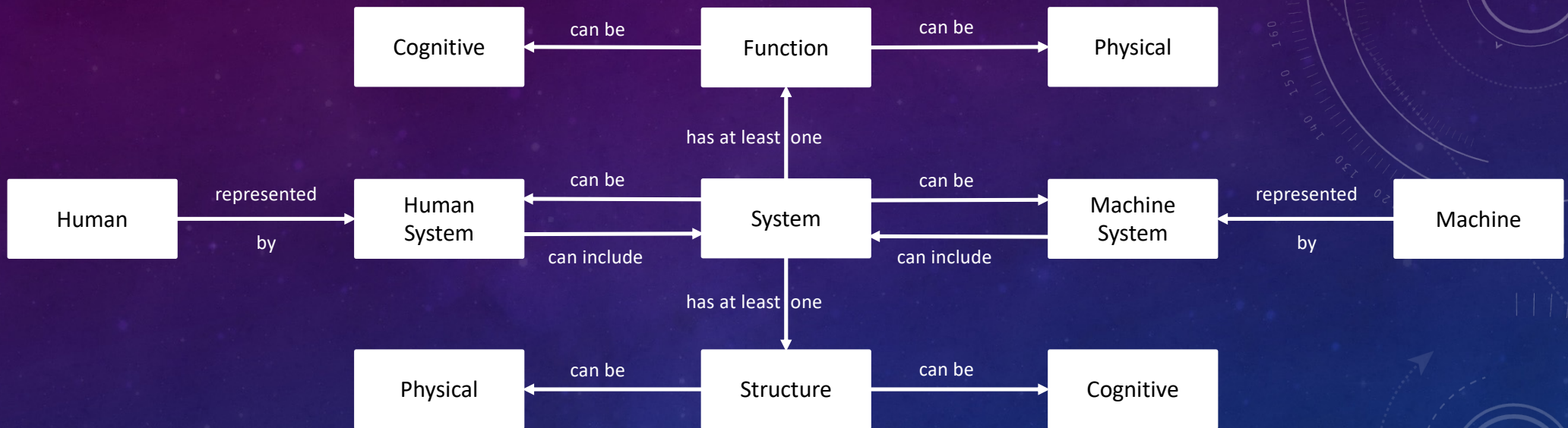
## People

- Problem-solving competence
- e.g., creativity & experience

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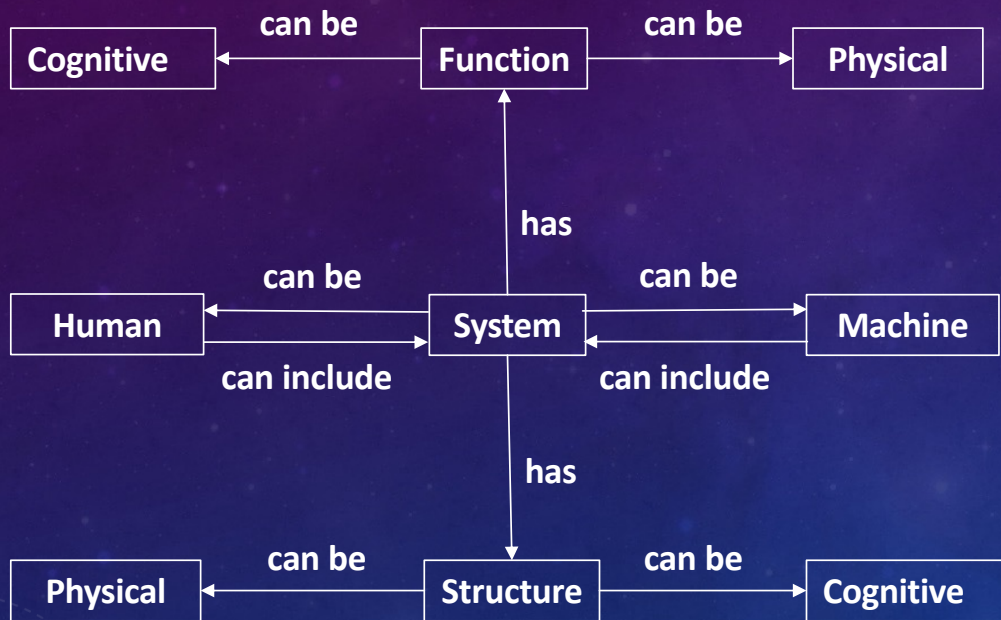
# INTEGRATION

## THE NEED FOR A SYSTEMIC ONTOLOGY

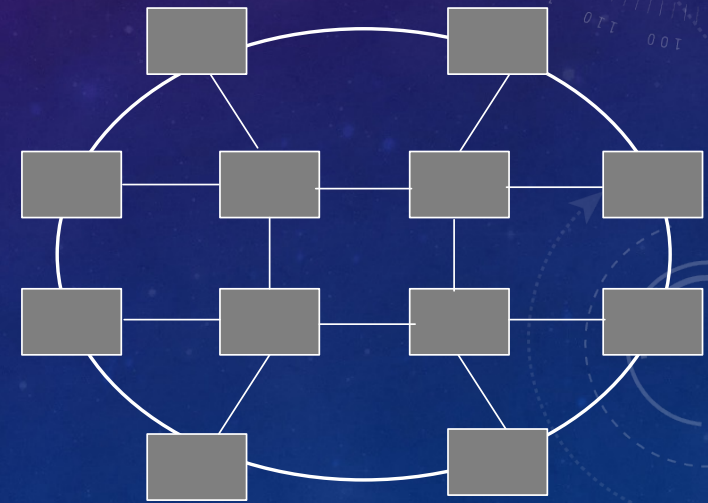
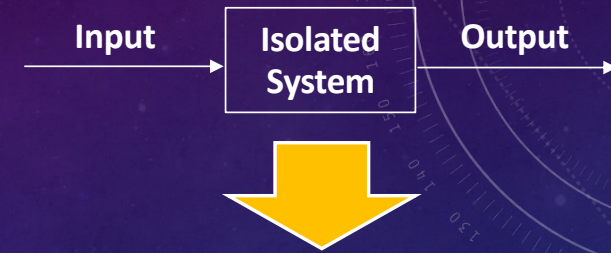


# SYSTEMS ARE REPRESENTATIONS OF NATURAL OR ARTIFICIAL ENTITIES

# WHAT IS A SYSTEM?



Systems include Humans and Machines...



Interconnected System of Systems



# SYSTEM = FUNCTION + STRUCTURE

Shared situation awareness  
Speed & precision  
Resilience  
Trust & Collaboration

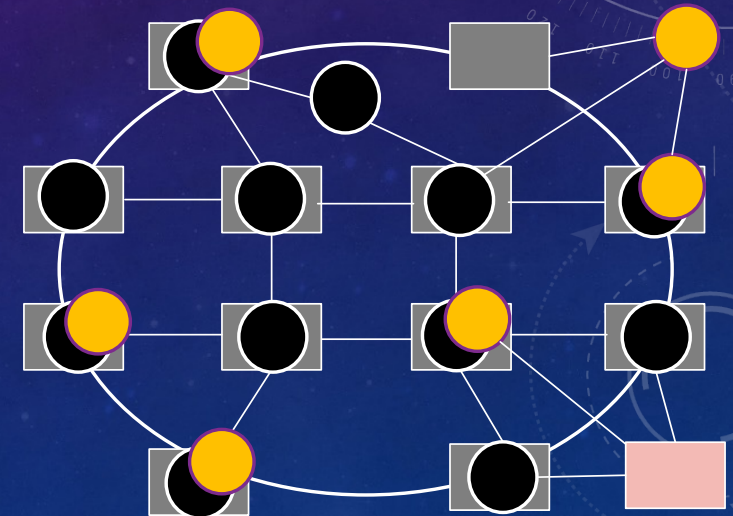


Interconnected Functions of Functions

Emergent Structures

Emergent Functions

Overlapping Functions of Functions

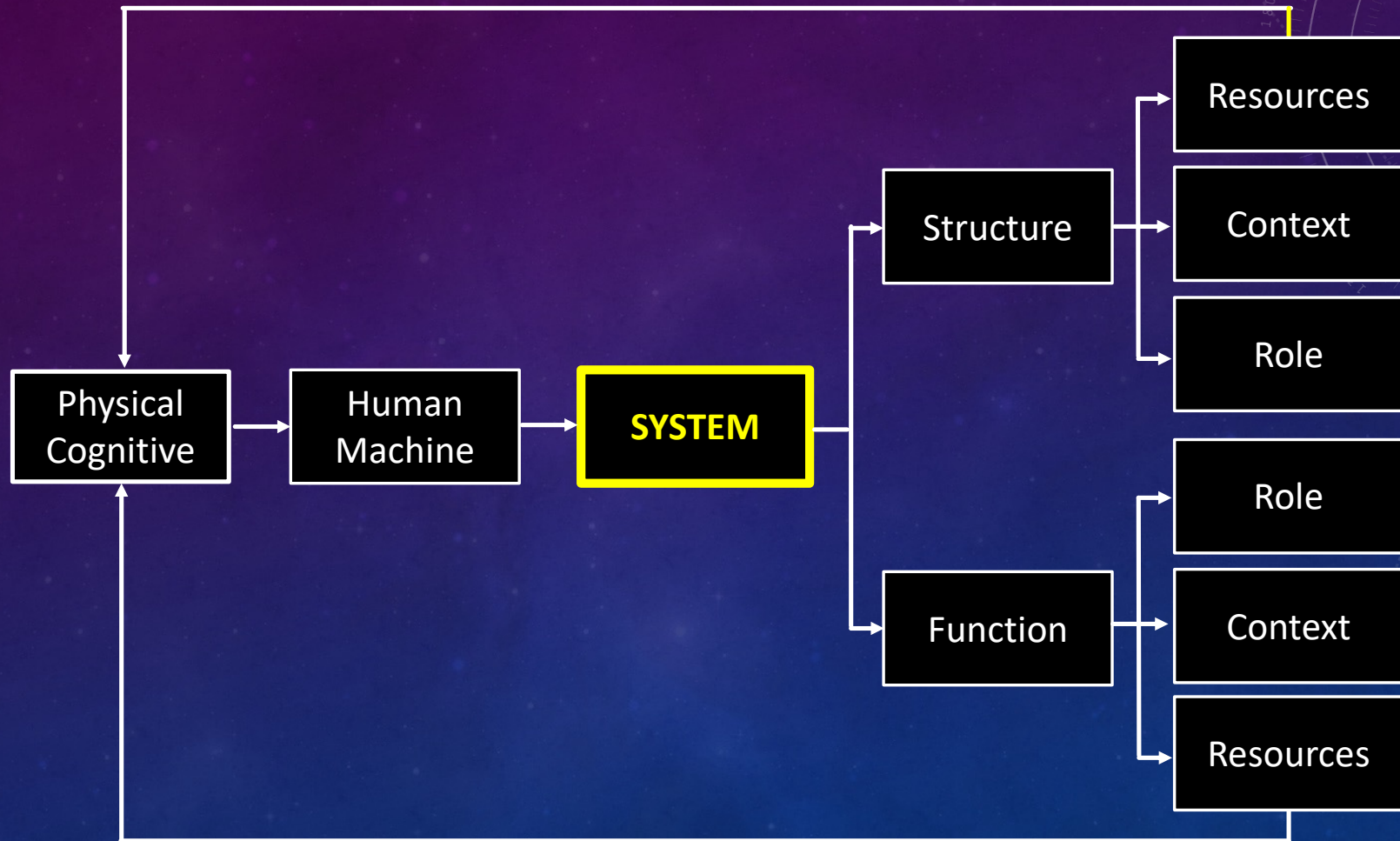


Interconnected Structures of Structures

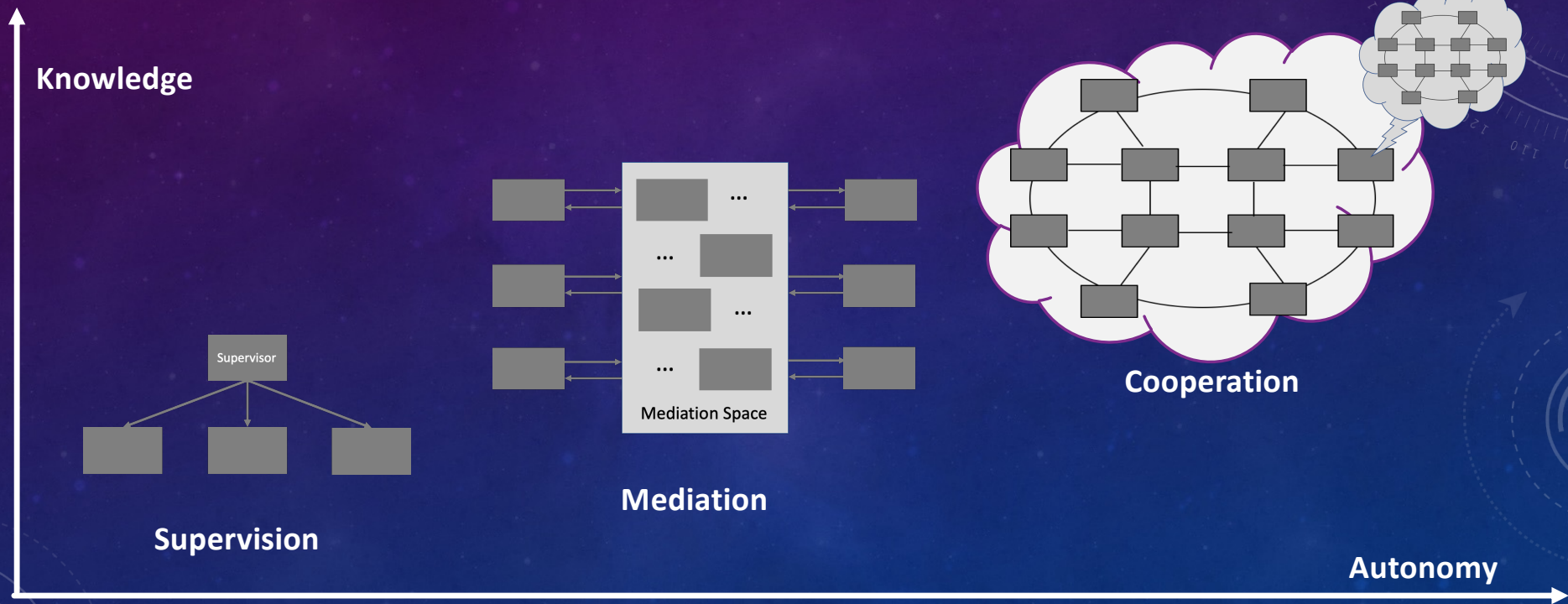
# SYSTEM = FUNCTION + STRUCTURE



# WHAT IS A SYSTEM?



# SYSTEMIC INTERACTION MODELS... ... AND AUTHORITY SHARING

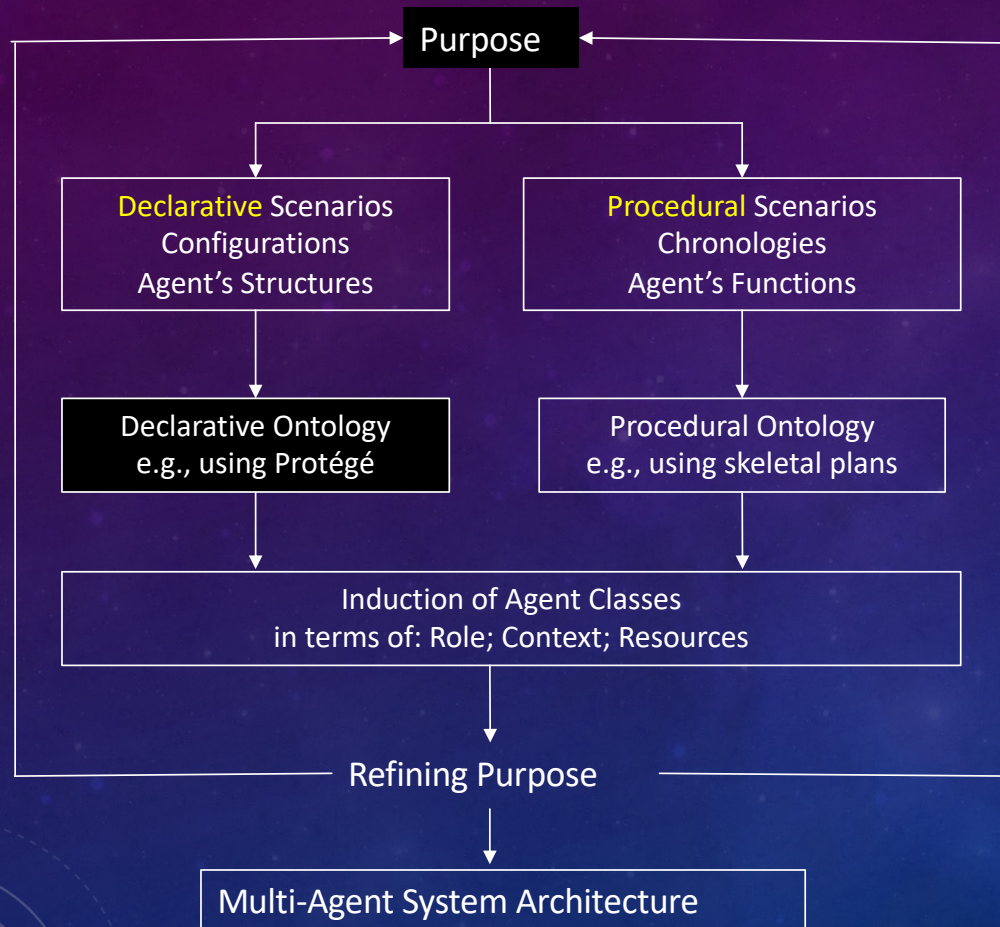


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# INTEGRATION

## FROM PURPOSE TO MEANS

# FROM PURPOSE TO MEANS



*What do we want to do?*

*Analysis of the existing so far...*

*Anticipating possible futures...*

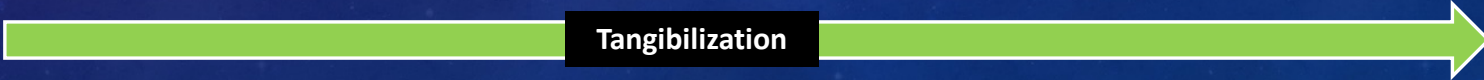
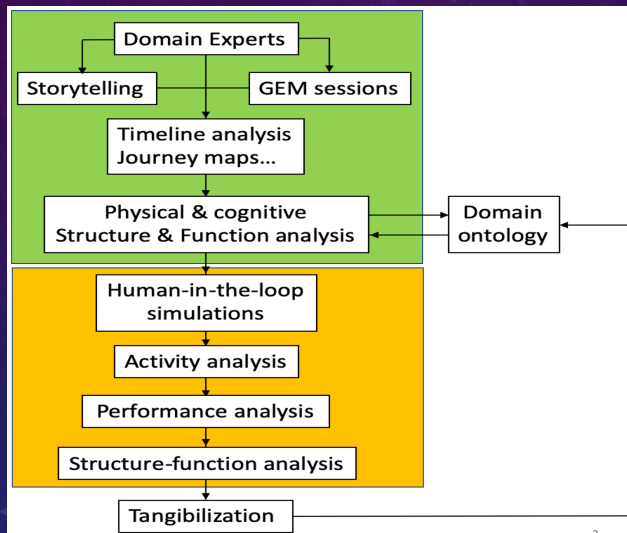
*Making a Multi-Agent Ontology*

*Becoming more generic...*

 **PRODEC**

# OFF-SHORE OIL & GAS MULTI-AGENT TELEROBOTIC SYSTEMS

Using PRODEC method combined with HITLS



# CONCLUDING...

Awareness of the various possible contexts!  
scenarios  
human-in-the-loop simulations  
elicitation of emergent cognitive functions

Scenario-based design → solid conceptual models

## *Orchestra Model pour design, evaluation and operations*

Music theory → common framework (interaction models)

Composers → scores = contracts + coordination

Conductors → dynamic re-allocation

Musicians → **competence + engagement + cooperation**

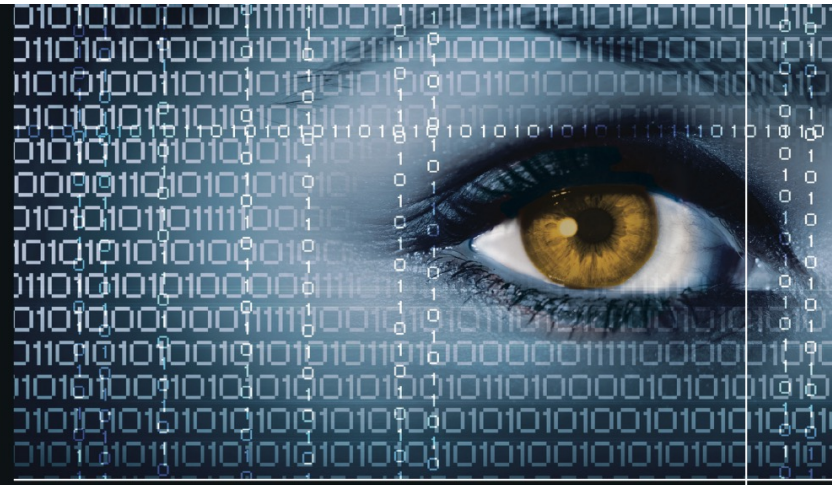
Audience → constant communication and education





# A FEW TAKE-AWAYS

- We live in a digital world → **tangibility** is a crucial contemporary issue
- Single-agent ergonomics is not enough → **Socio-ergonomics**
- Human-machine teaming → what **new human roles**?
- Rigid automation is what we know → **Flexible autonomy** is what we need to make
- How do we deal with the unexpected? → **problem-solving support**
- From means to purpose (people adapt) → **From purpose to means** (machines adapt)
- Collaborative work requires **education, openness, empathy** and **enthusiasm!**



HUMAN-SYSTEMS INTEGRATION

# HUMAN-SYSTEMS INTEGRATION

From Virtual to Tangible

Guy Andre Boy

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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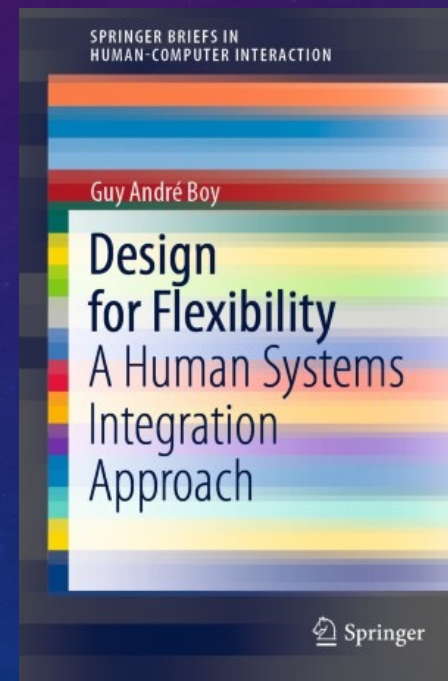
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... and another one on flexibility!



Thank you!

