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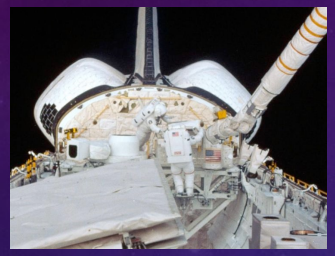
SYNTHESIS LESSON

HUMAN SYSTEMS INTEGRATION
IN THE DESIGN OF INCREASINGLY AUTONOMOUS SYSTEMS

Prof. Guy André Boy

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

MY WORLD FOR THE LAST ~45 YEARS ...



... in technical design
and operations

Human Factors & Ergonomics ...
Human-Centered Design ...
Human Systems Integration ...

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HUMAN SYSTEMS INTEGRATION (HSI) FOR INCREASINGLY AUTONOMOUS SYSTEMS

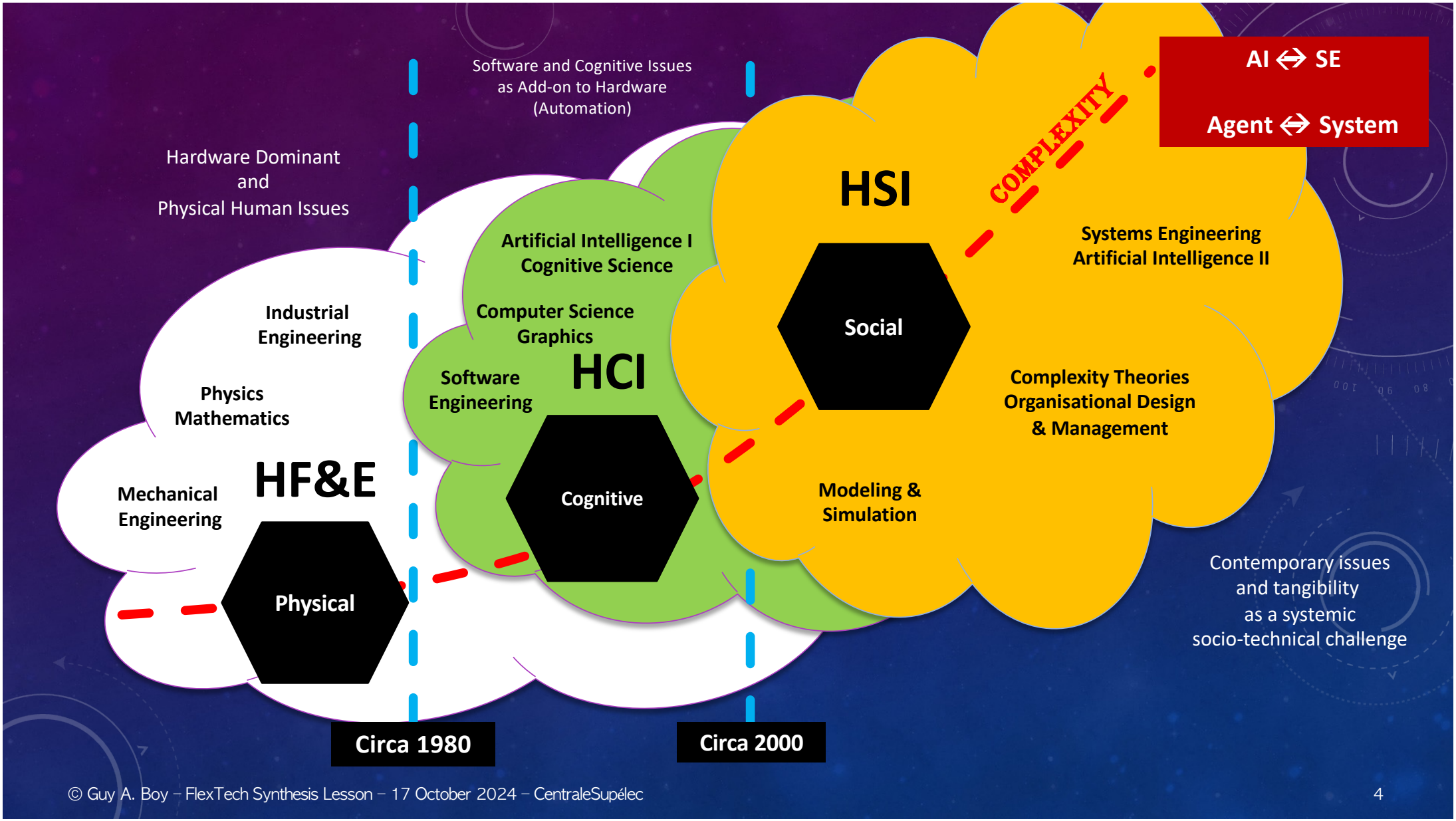
Design for Flexibility, HSI & Autonomy…

Digital engineering: human-centered design, flexibility, uncertainty, tangibility, maturity, etc.

Roles of people & organizations in life-critical systems: sociotechnical, ethical & epistemological issues

Development of new approaches, methods & tools, e.g., digital twins, human-in-the-loop simulations, etc.

Applications in various industrial sectors, e.g., aerospace, defense, energy, health, automotive, nuclear, etc.


Software and Cognitive Issues
as Add-on to Hardware
(Automation)
Hardware Dominant
and
Physical Human Issues
AI ⇔ SE
Agent ⇔ System
COMPLEXITY
HSI
Artificial Intelligence I
Cognitive Science
Computer Science
Graphics
Software
Engineering
HCI
Industrial
Engineering
Physics
Mathematics
HF&E
Mechanical
Engineering
Physical
Cognitive
Social
Systems Engineering
Artificial Intelligence II
Complexity Theories
Organisational Design
& Management
Modeling &
Simulation
Contemporary issues
and tangibility
as a systemic
socio-technical challenge
Circa 1980
Circa 2000

Human-Factor & Ergonomics
Task & Activity Analysis
Human & Organizational
Performance Evaluation & Metrics

Information Technology
Human-Computer Interaction
Artificial Intelligence
Visualization techniques
Modeling & Simulation

Integrated Logistics Support & Maintenance

Workforce Planning

Safety

Environment

Human Factors Engineering

Competences & Professionalism

People

Organization

HSI

HSI Planning

Sustainability

Training

Habitability

Technology

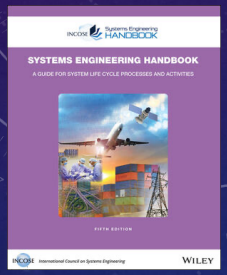
Systems Engineering
Sociotechnical Systems
Systems of Systems
Agile Development
Design & System thinking
Model-Based SE

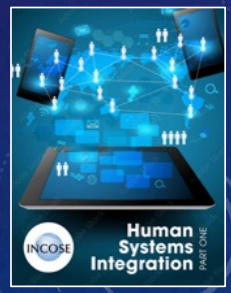
Social, Cultural & Organizational Factors

UX/Usability

Occupational Health

Operational Domain
Operational Expertise & Experience
Scenario Elicitation
Experimental test personnel





From Rigid Automation to Flexible Autonomy

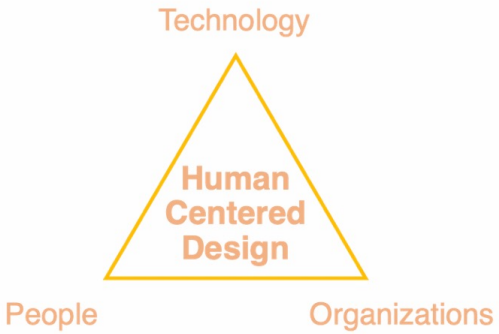
FlexTech Chair philosophy is based on **human-centered design** (HCD) and creativity, collaborative work, cognitive engineering, complexity analysis, organization design and management, modeling and human-in-the-loop simulation, artificial intelligenece, advanced interaction media, and the study of life-critical systems.

HCD combined with Systems Engineering leads to Human Systems Integration (HSI).

We automated a lot during the 20th century increasing safety, efficiency and comfort in nominal situations,
but leading to rigidity in off-nominal situations.

It is time to develop research and innovation on flexibility that increases autonomy of technology, organizations and people.

This is the shift from HighTech to FlexTech.



https://www.flextechchair.org/about.html

TECHNOLOGY-CENTERED ENGINEERING & MECHANICAL INDUSTRY

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20TH CENTURY APPROACH

Engineering
Ergonomics
HCI
Automation

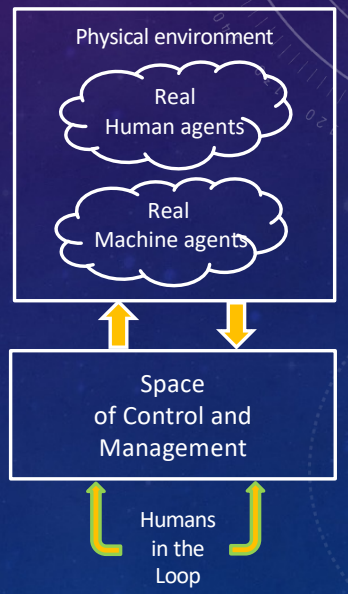
From hardware
... to software

Engineering

Ergonomics
Automation

Pilots
+
Aero personnel

People adapt
to Machines



Inside-out

HUMAN SYSTEMS INTEGRATION & DIGITAL INDUSTRY

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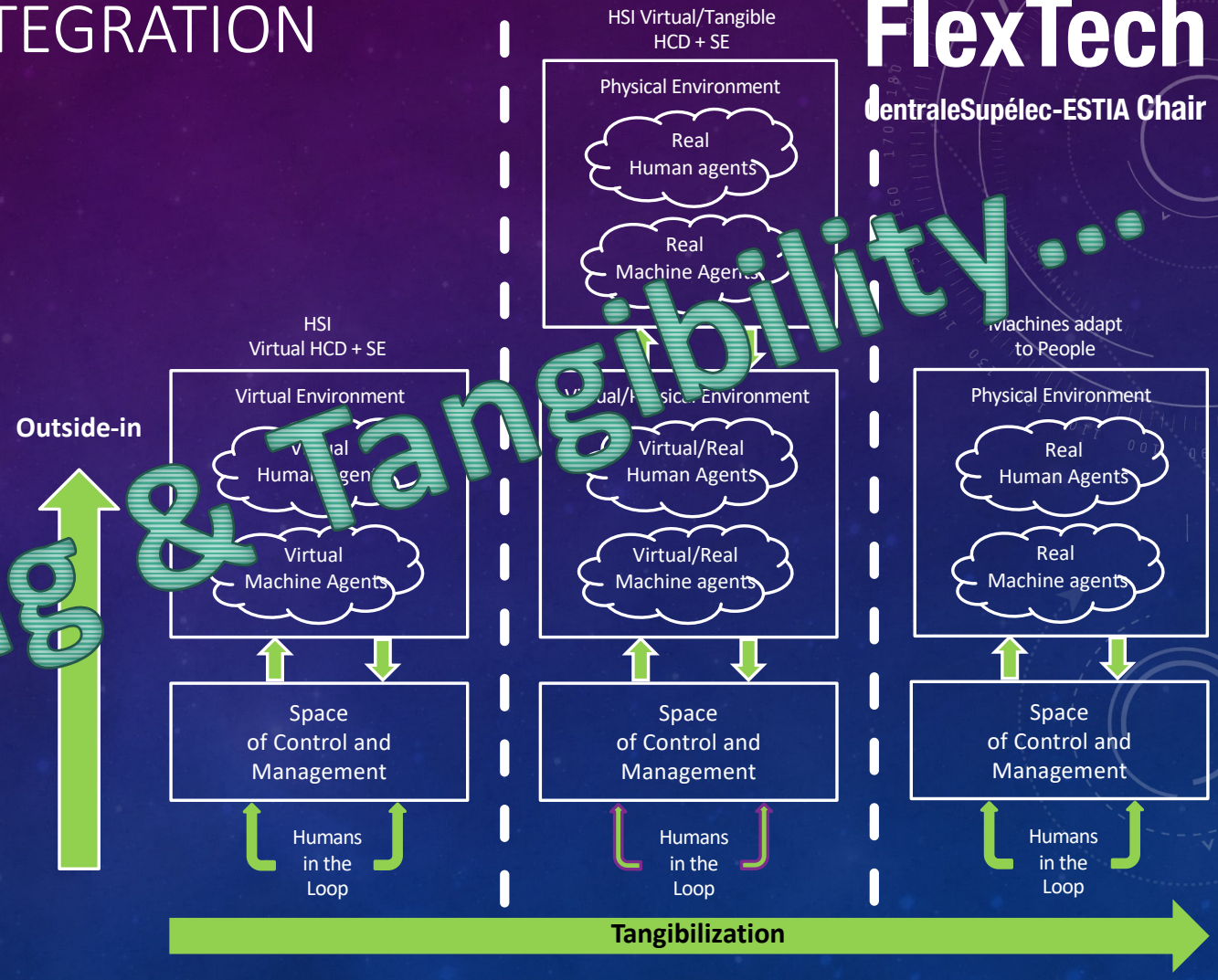
21ST CENTURY APPROACH

Human-centered design (HCD)
Systems engineering (SE)
Human-in-the-loop digital simulation
Artificial Intelligence & Data Science
Organization Sciences

From software
... to hardware

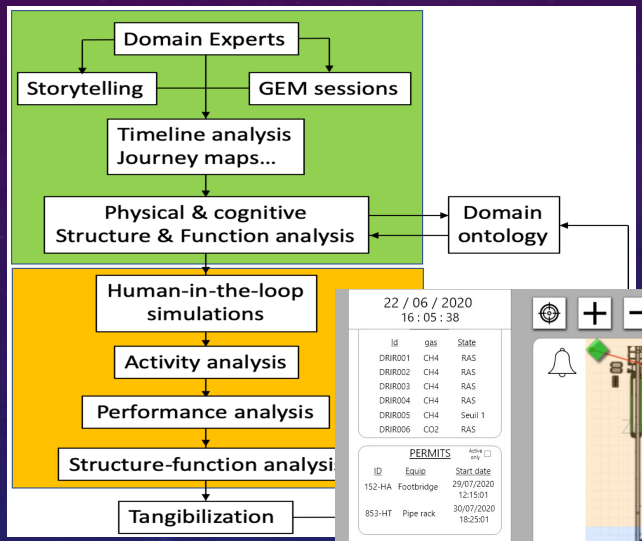
Meaning & Tangibility...

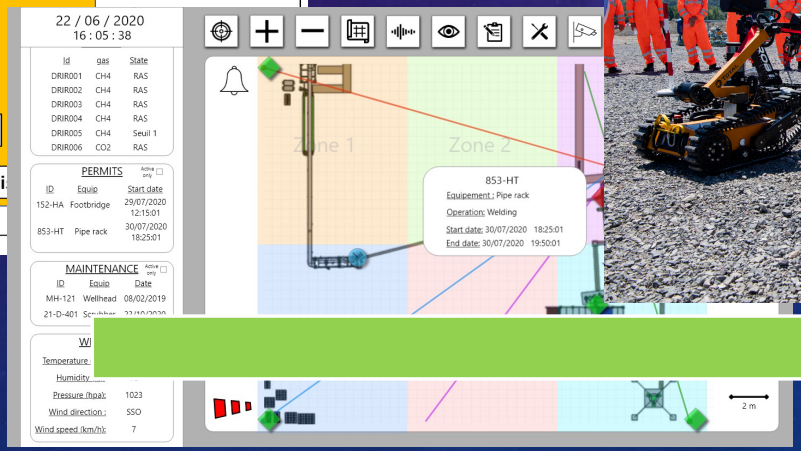


MULTI-AGENT TELEROBOTIC SYSTEMS FOR OFFSHORE OIL & GAS WELLS

Situational awareness, decision-making & risk-taking

Using the PRODEC method and human-in-the-loop simulation





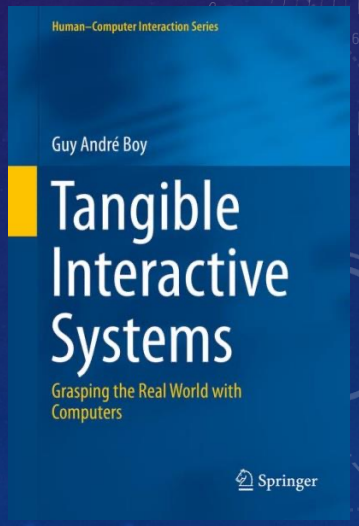
Tangibilization

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, ...
- Durability: design rationale, knowledge management, ...

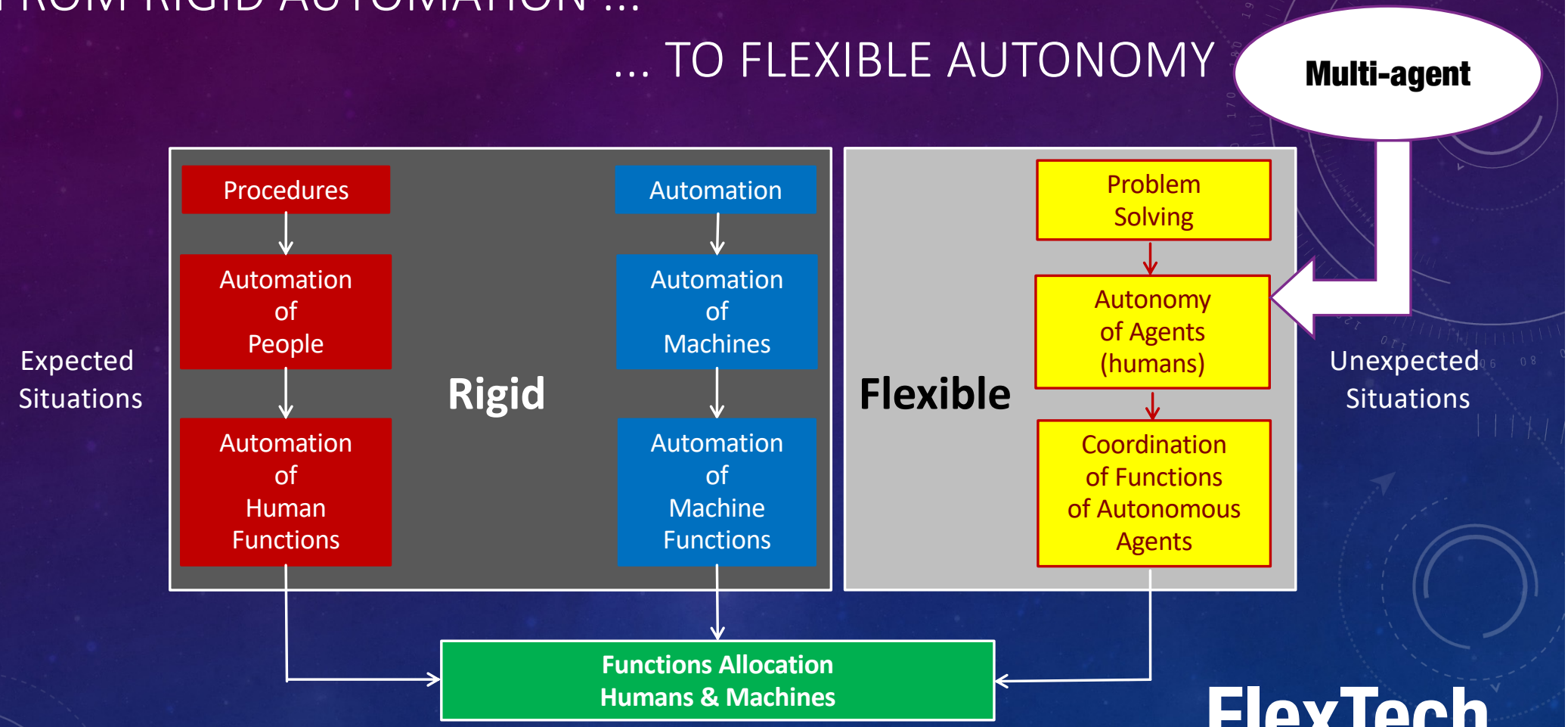
+ Sociotechnical Factors

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



FROM RIGID AUTOMATION ...

... TO FLEXIBLE AUTONOMY



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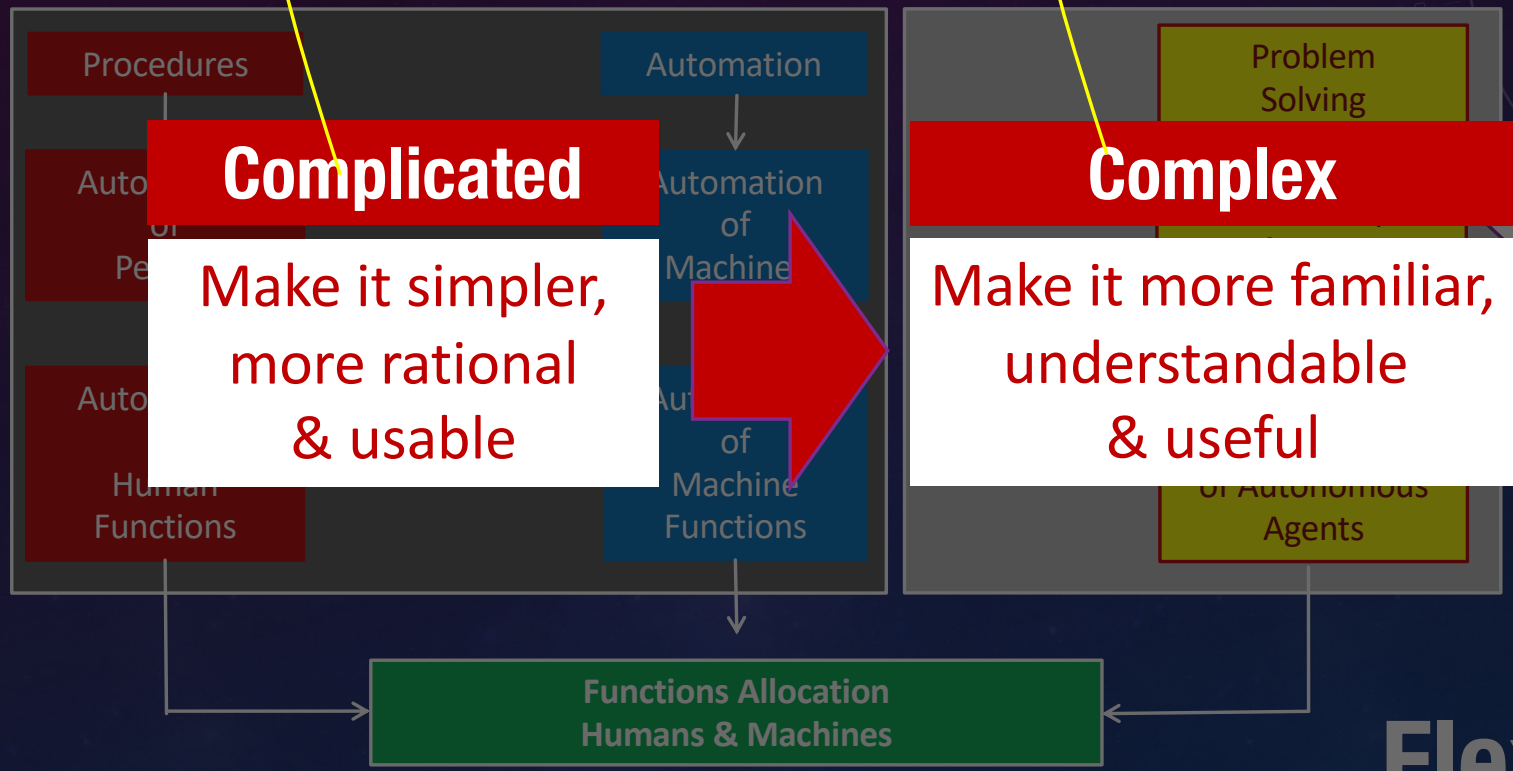
FROM RIGID AUTOMATION ... TO FLEXIBLE AUTONOMY

Optimization & Reductionism

Maturity

Multi-agent



Complicated

Make it simpler, more rational & usable

Complex

Make it more familiar, understandable & useful

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READINESS LEVELS

Technology (TRL)

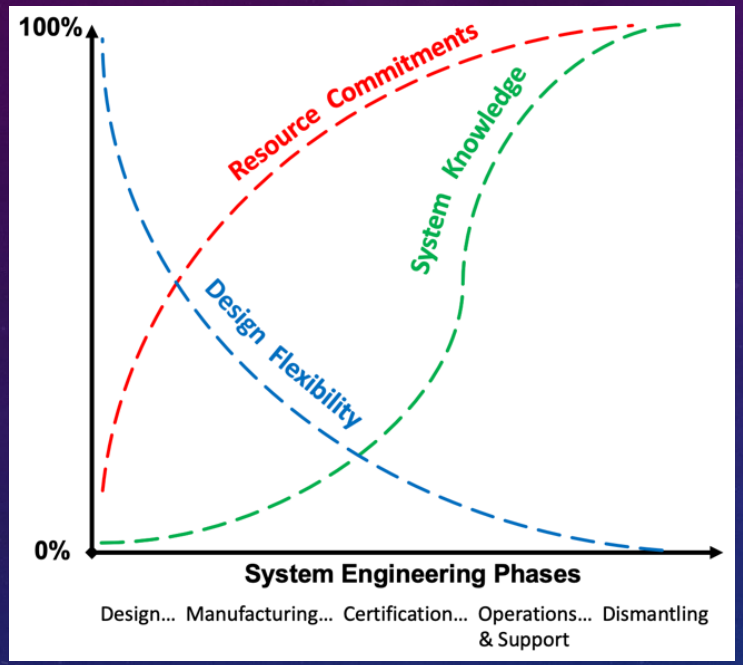
Human (HRL)

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

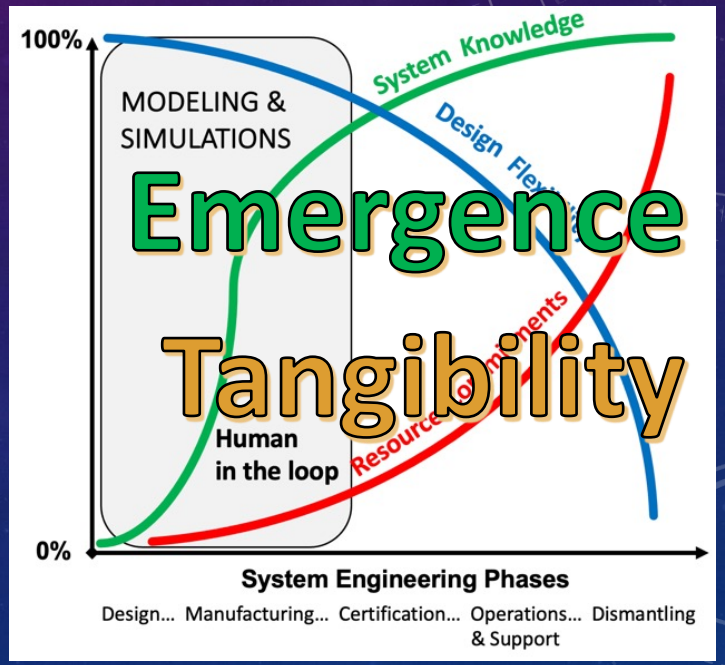
Organization (ORL)

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

TECHNOLOGY-CENTERED ENGINEERING:
STILL LAGGING BEHIND
IN THE LIFE CYCLE



HUMAN-CENTERED DESIGN:
WHAT WE REALLY WANT



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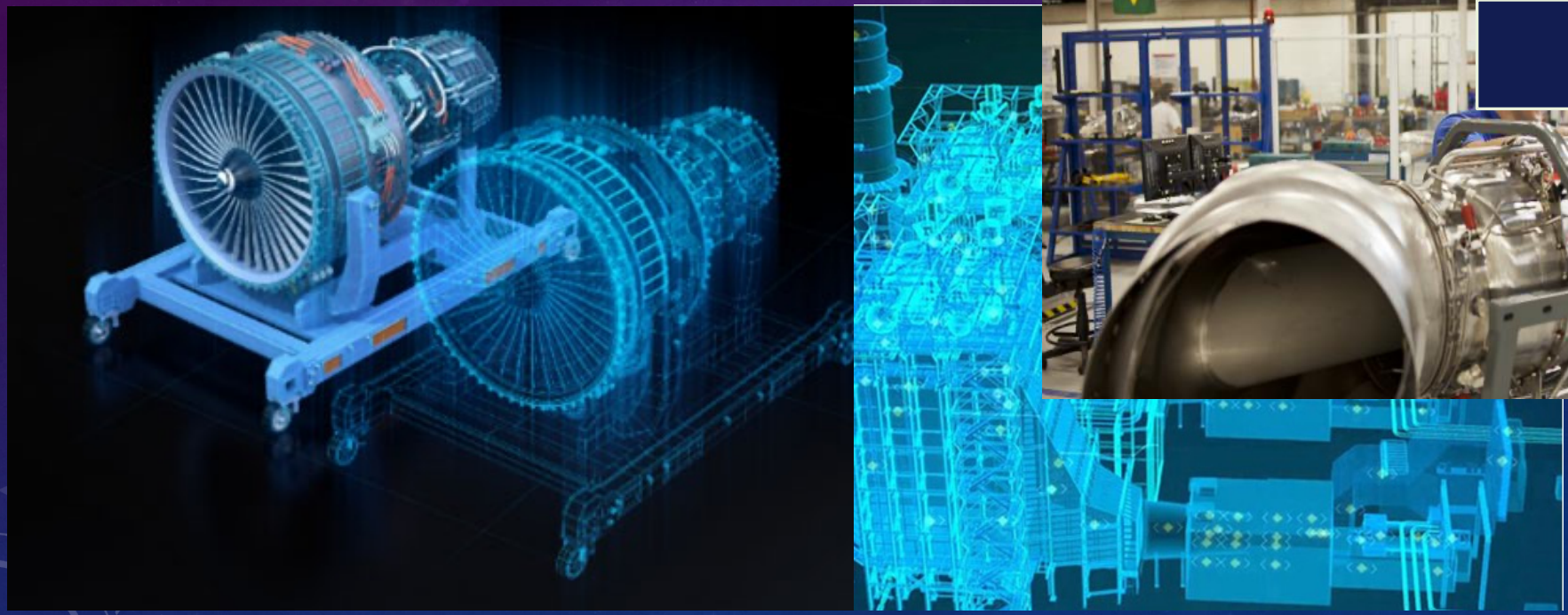
A DIGITAL TWIN FOR HELICOPTER ENGINE MAINTENANCE

Situational awareness, decision-making, trust & collaboration



DIGITAL TWINS
VIRTUAL

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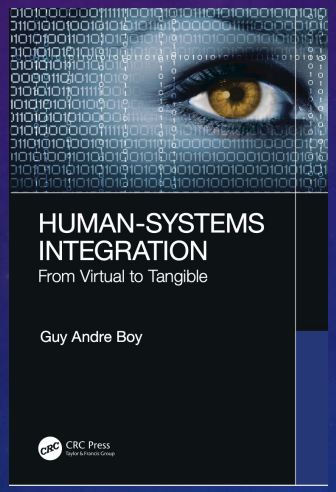
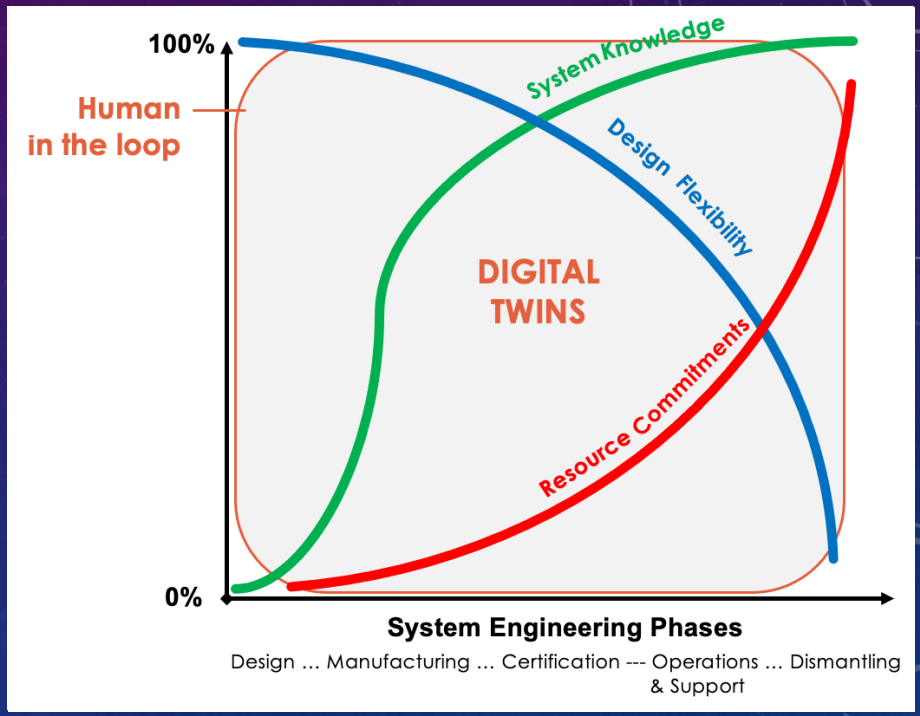
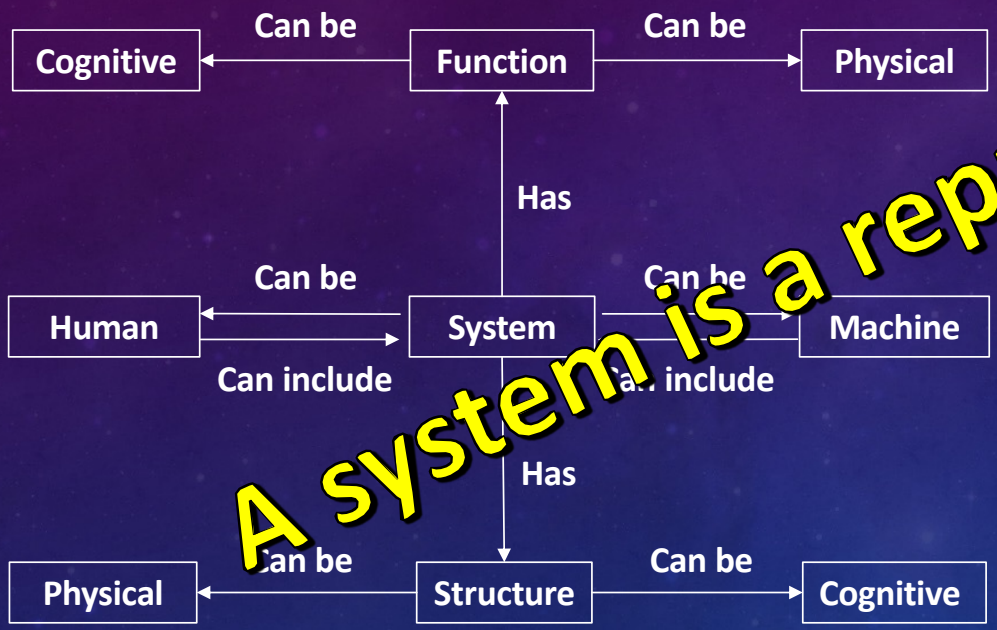
- Expanding human-in-the-loop simulations
  - during the whole life cycle of a system
  - "**what if?**"
- Vivid documentation
  - Experience feedback integration
  - **Organizational memory**
- Digital twins as Virtual Assistants
  - Multi-agent collaboration
  - Mediators for **collaborative work**





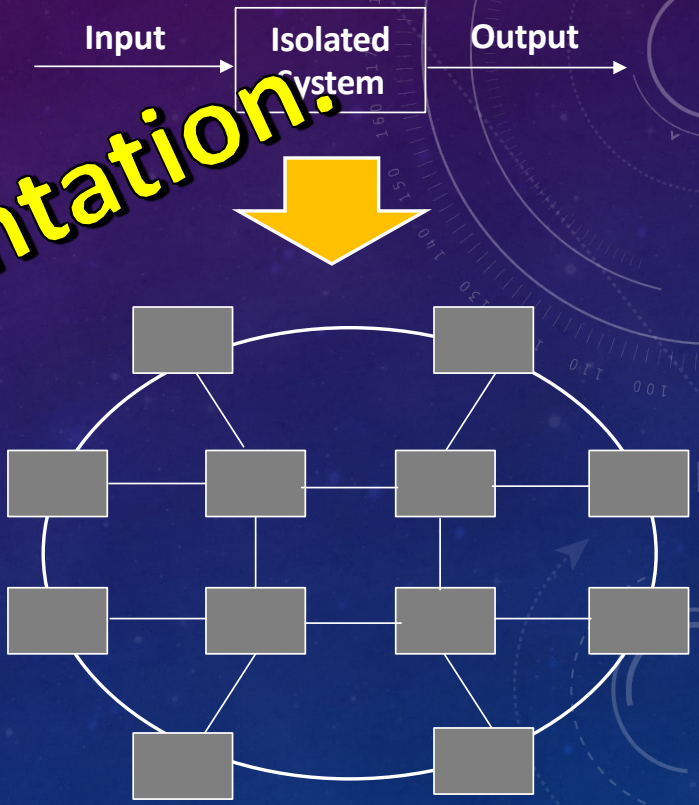
WHAT'S FUNDAMENTAL HERE?

WHAT IS A SYSTEM?



Systems include Humans and Machines...

A system is a representation.



Interconnected Systems of Systems

SYSTEM = STRUCTURE + FUNCTION

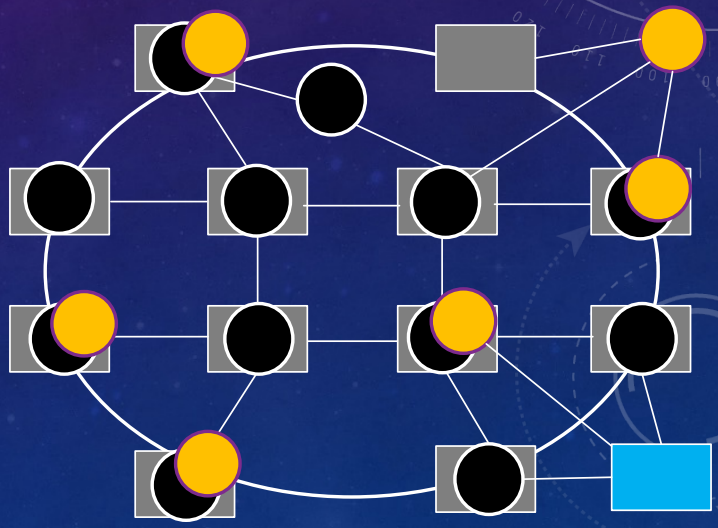
Emerging Structures

Emerging Functions

Shared situational awareness
Speed & precision
Resilience

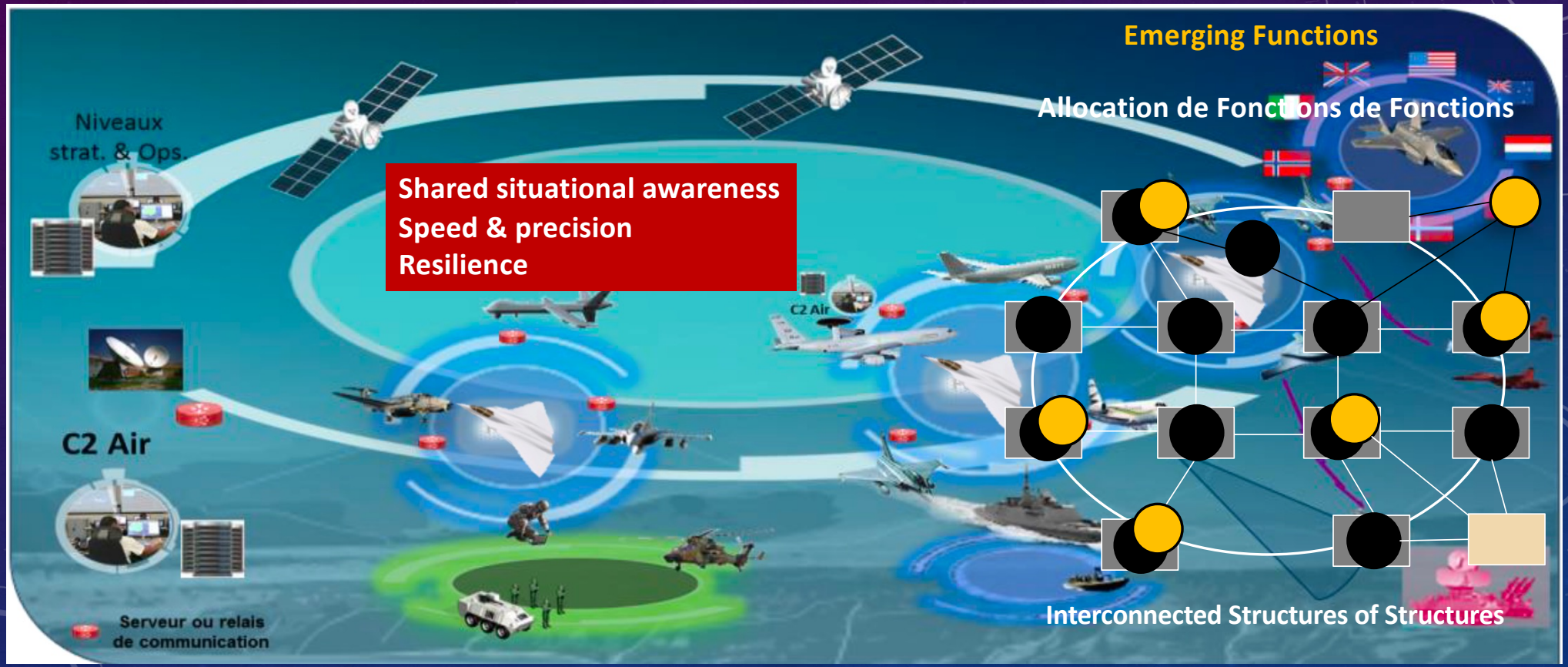
Interconnected Functions of Functions

Allocation of Functions of Functions

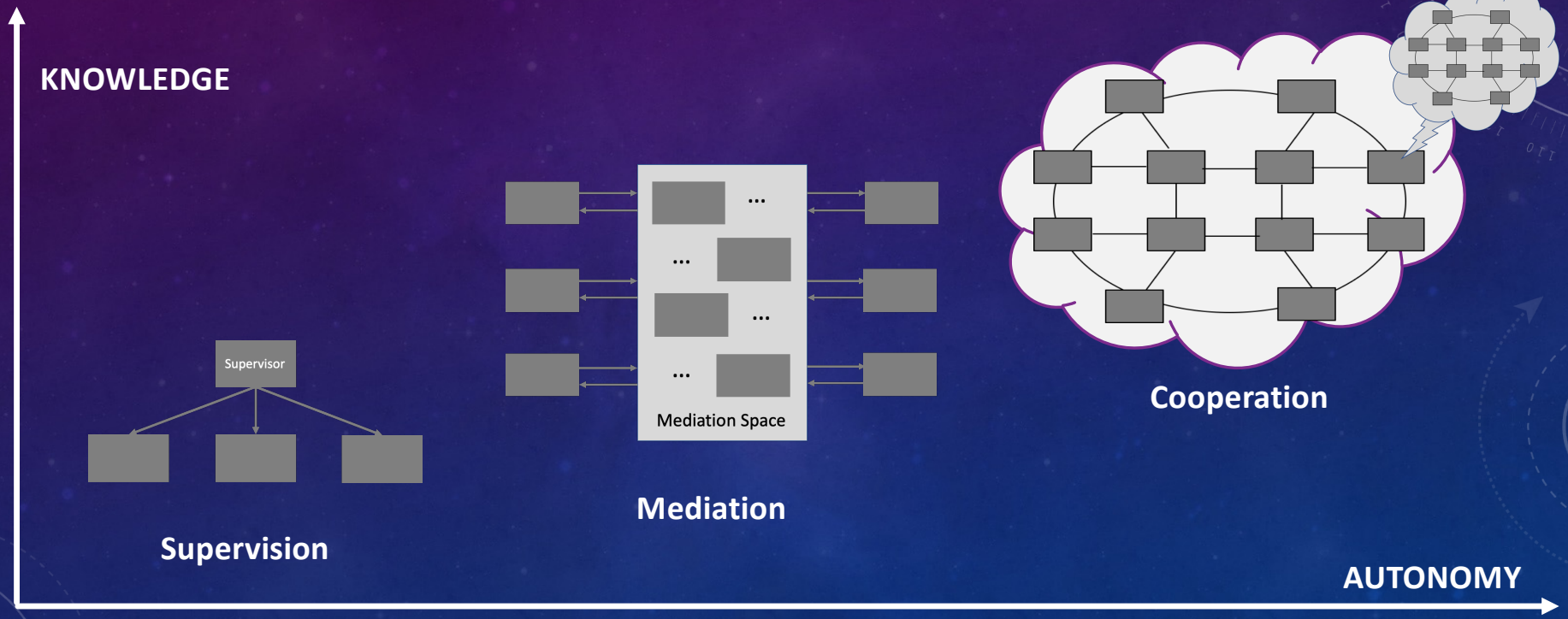


Interconnected Structures of Structures

SYSTEM = STRUCTURE + FUNCTION



SYSTEMIC INTERACTION MODELS …
… AND AUTHORITY SHARING

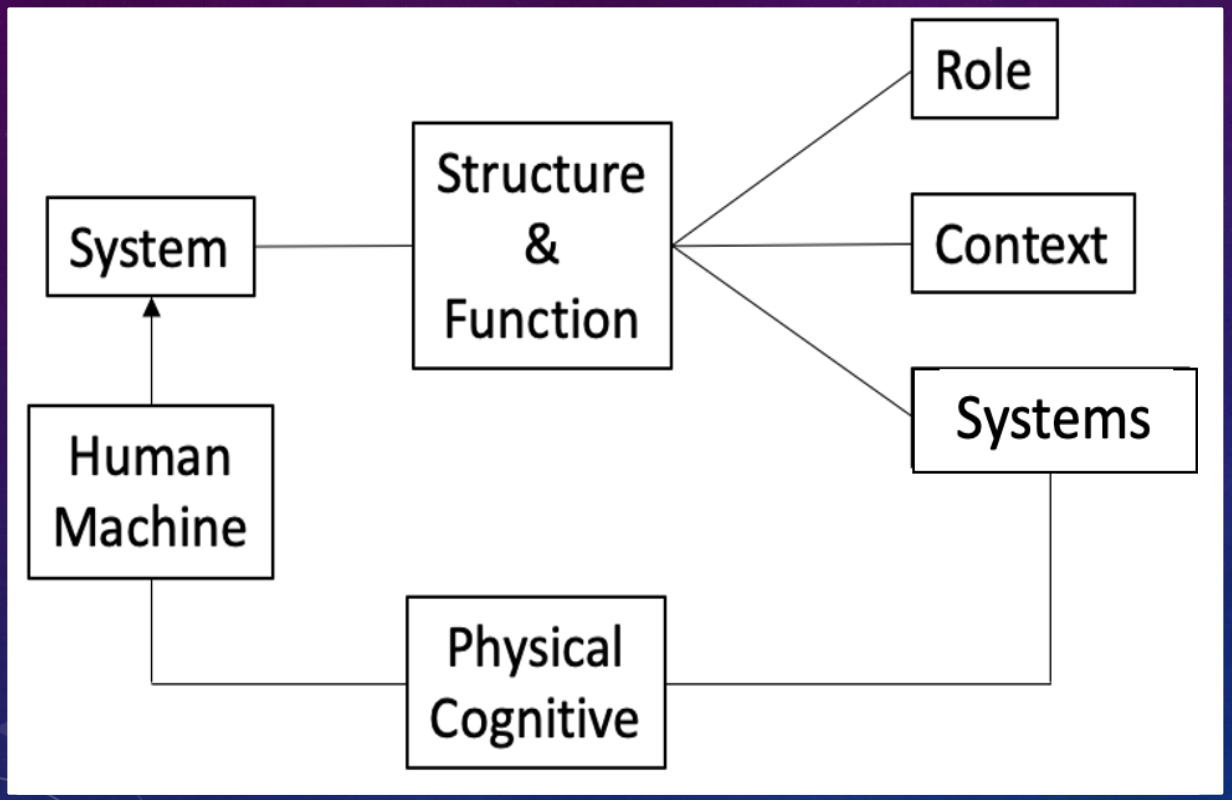


TOWARD AN ONTOLOGY OF HSI…

… AND MODEL-BASED HSI

A SYSTEM AS A DECLARATIVE ENTITY

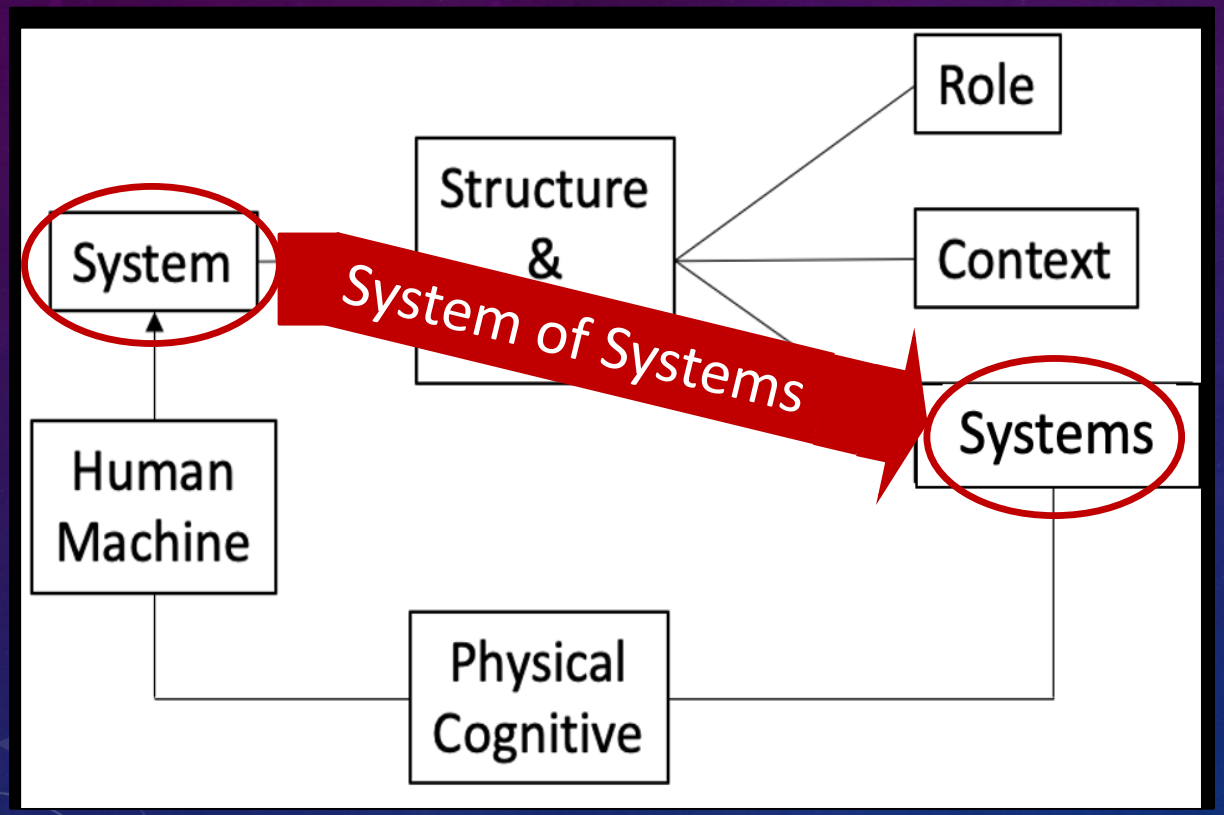
PRODEC



SYSTEM SPACE

A SYSTEM AS A DECLARATIVE ENTITY

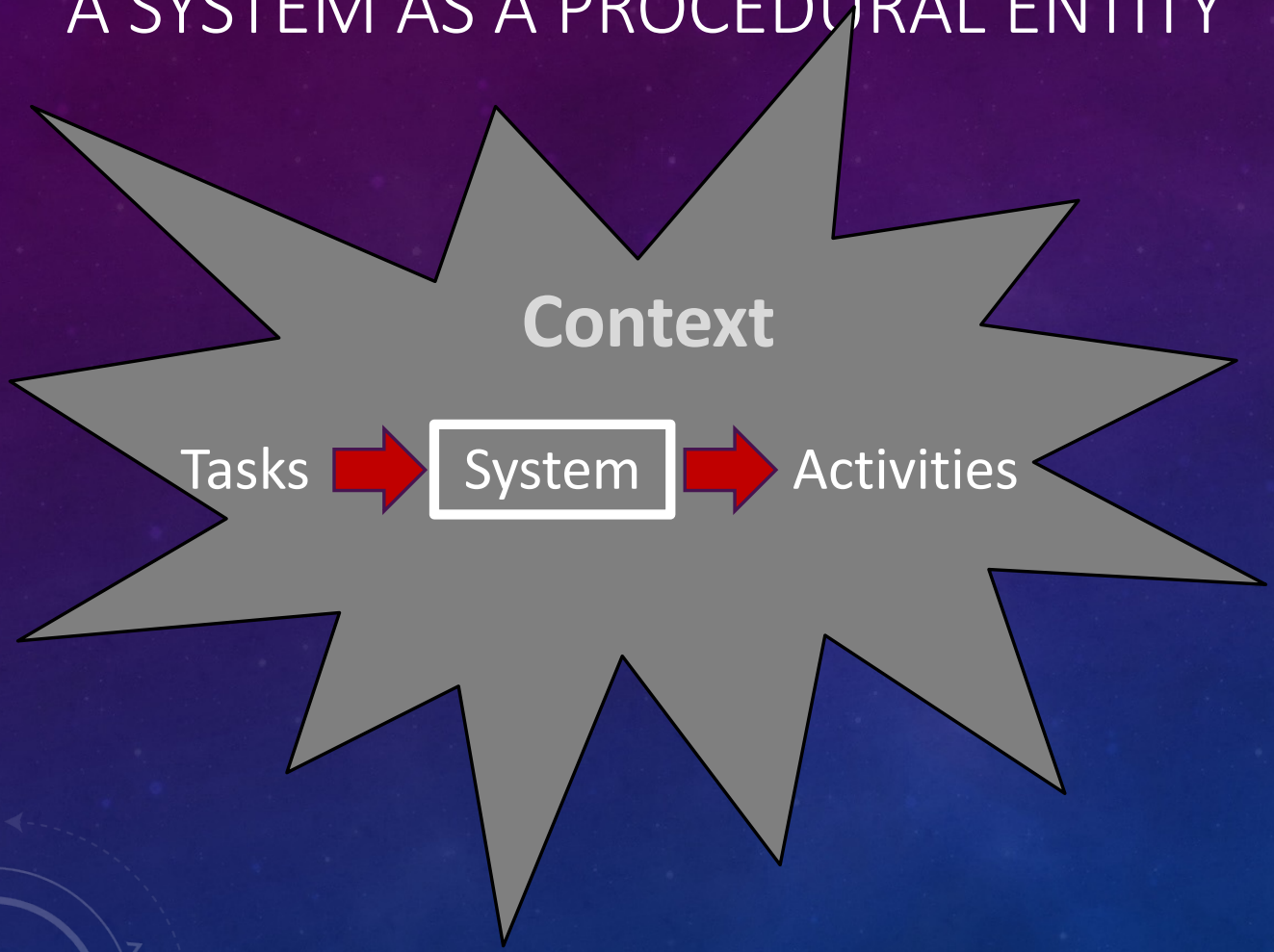
PRODEC



SYSTEM SPACE

A SYSTEM AS A PROCEDURAL ENTITY

PRODEC

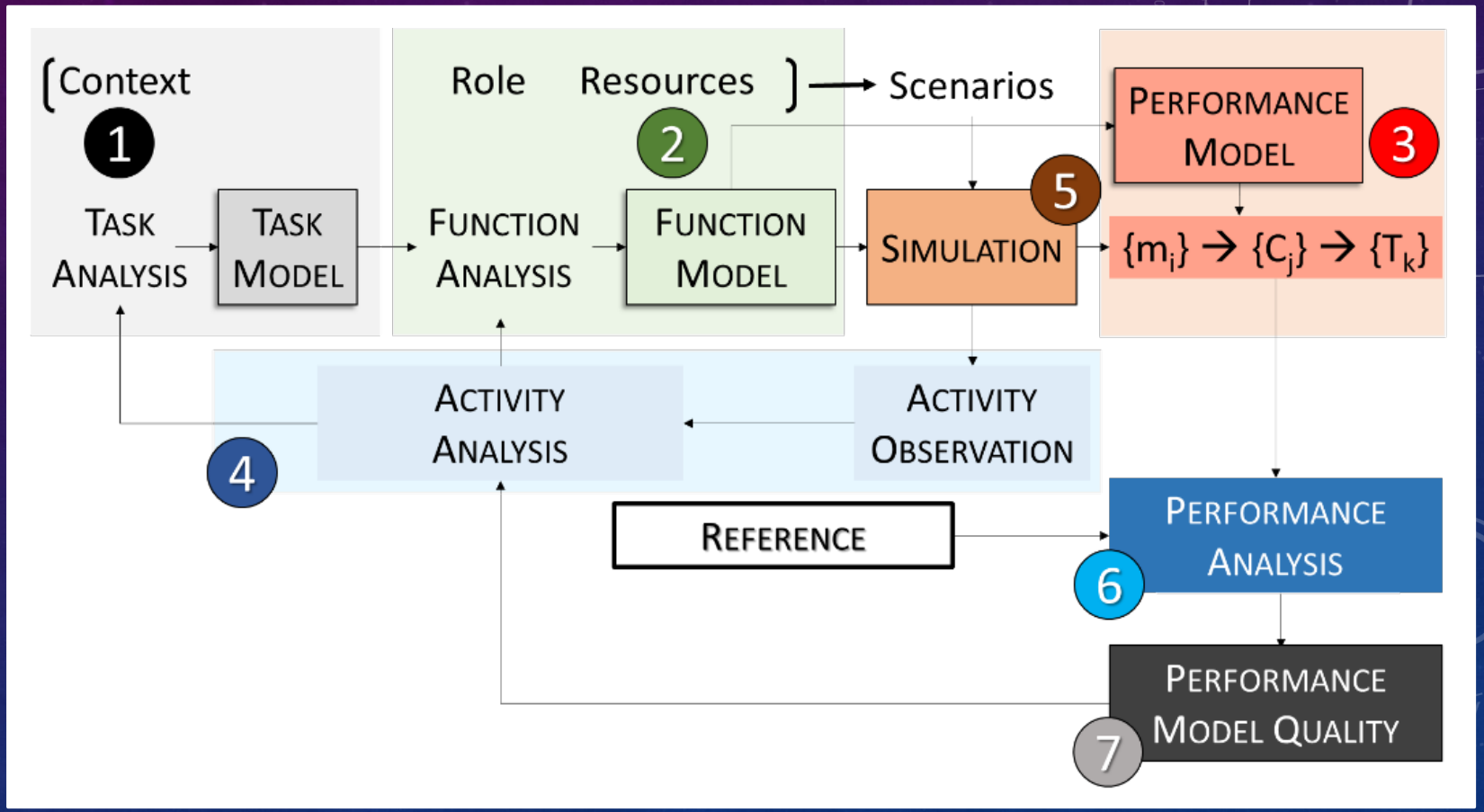


CONTEXT SPACE

CONTEXT DEALS WITH:

- TIME & SPACE
- HISTORY & CONFIGURATIONS
- DIVERSITY & EXCEPTIONS
- …

MOHICAN PRODEC



SYNAPSE DÉFENSE

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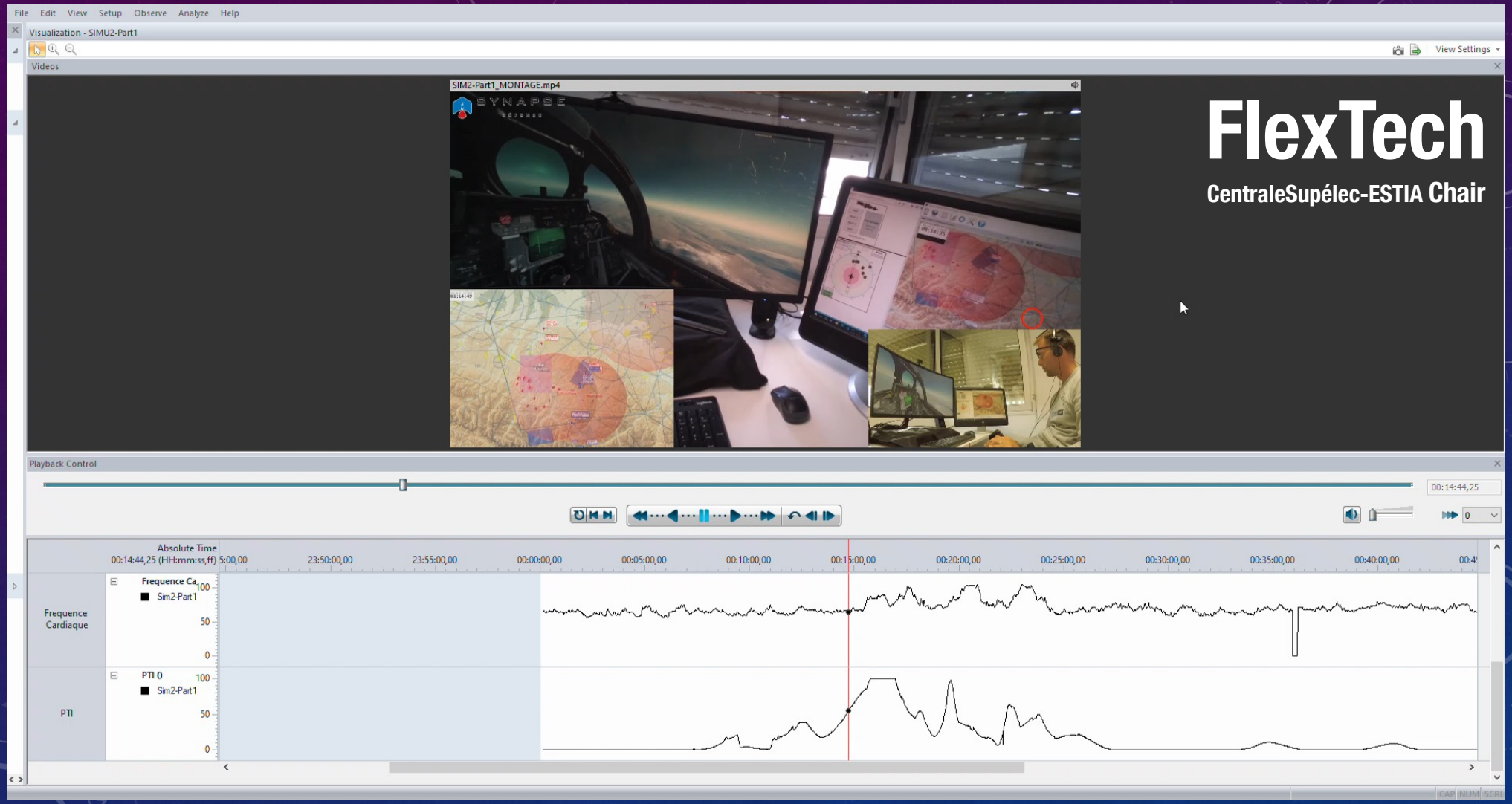
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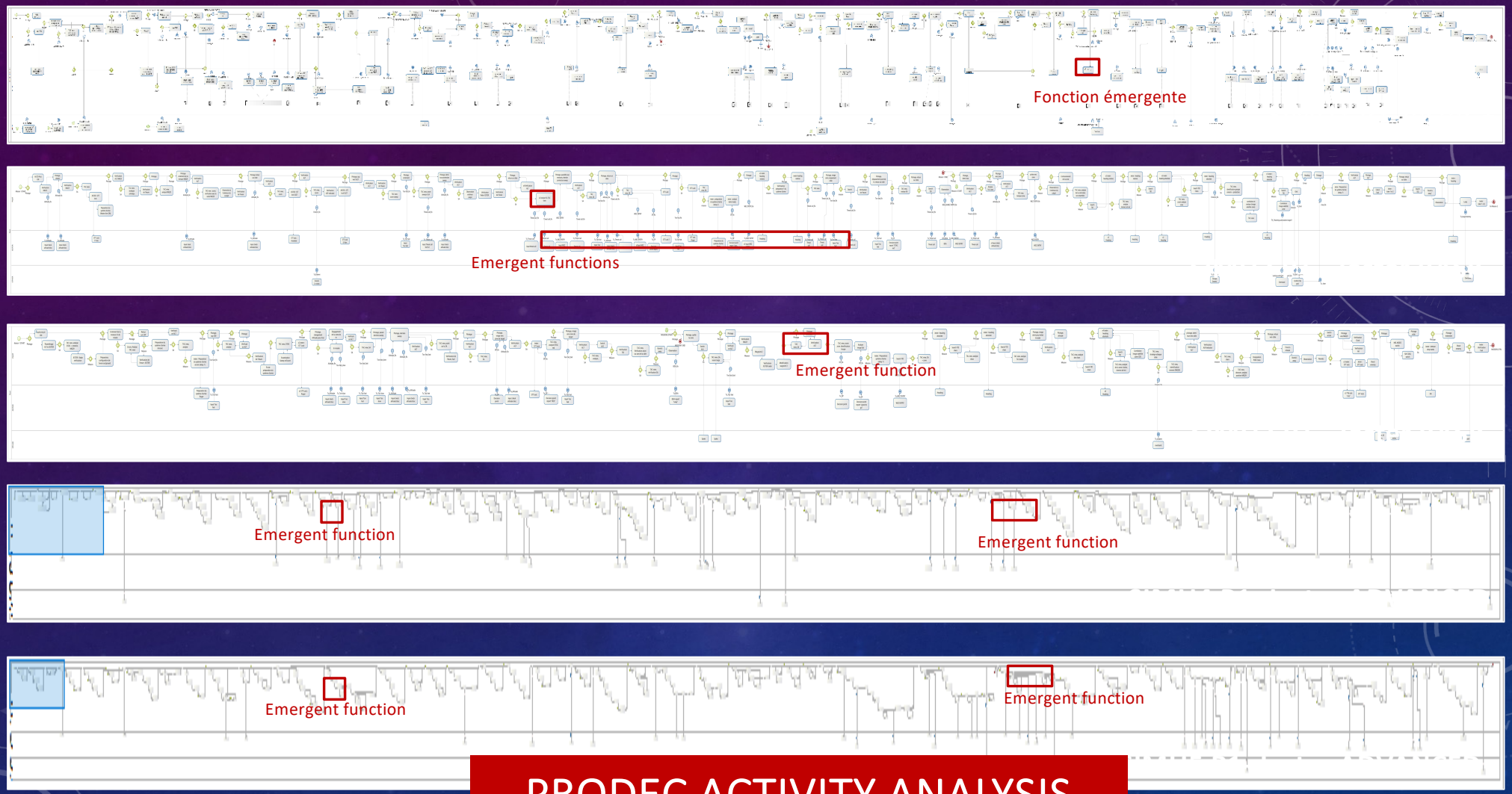
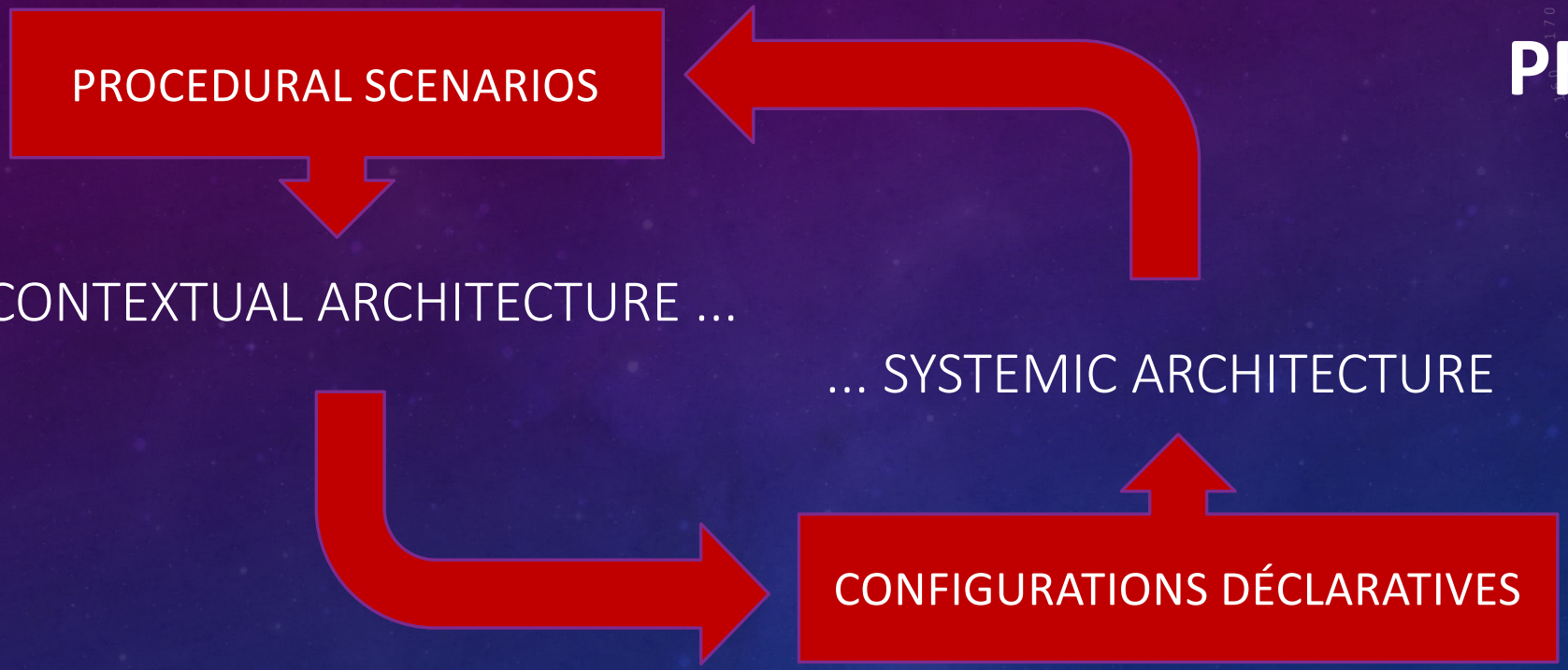


PRODEC ACTIVITY ANALYSIS

OPERATIONS

PRODEC

PRODEC



DESIGN ENGINEERING

WHAT HAVE WE DONE IN 5 YEARS?

FlexTech
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- **Worked with industry**: TotalEnergies; CS Group; Thales; DGA; Safran; SNCF; CNES; Ingenuity
- **Expanded our academic network**: ISAE-SUPAERO; ENSC; ESCP; IRIT
- Developed an **HSI framework and ontology**
- Developed **PRODEC** method
- Developed and taught an **HSI Course**: CentraleSupélec; ESTIA; ISAE-SUPAERO; ESCP
- Gave **webinars**: INCOSE; EUROCONTROL; FAA
- **Published** articles and books: INCOSE; IEA; IFAC; IEEE
- Organized **international events and trainings**: HSI2019; HSI 2021; HSI2024; workshops; HSI-HAT Spring School

HSI2024

INTERNATIONAL CONFERENCE
JEJU, KOREA
27-29 AUGUST 2024

2024 FlexTech Industrial International Spring School on Human-AI Teaming (HAT)

A Human Systems Integration Approach

29-31 May 2024 - Radisson Blu, Biarritz, Basque Country, France

Purpose

- intensive week-long training and exchange seminar
- introduction to Human Systems Integration
- integrating artificial intelligence (AI), systems engineering, human factors & ergonomics, and human-computer interaction
- through incremental tangibilization of virtual prototypes

Logistics

- Radisson Blu Hotel, Biarritz, France
- with the best senior scientists and practionners
- limited to 60 participants worldwide
- arrival Sunday evening & departure Friday afternoon

https://www.flextechchair.org/FTSpringSchool2024/about.html

MAJOR REFERENCE PRODUCTIONS

FlexTech
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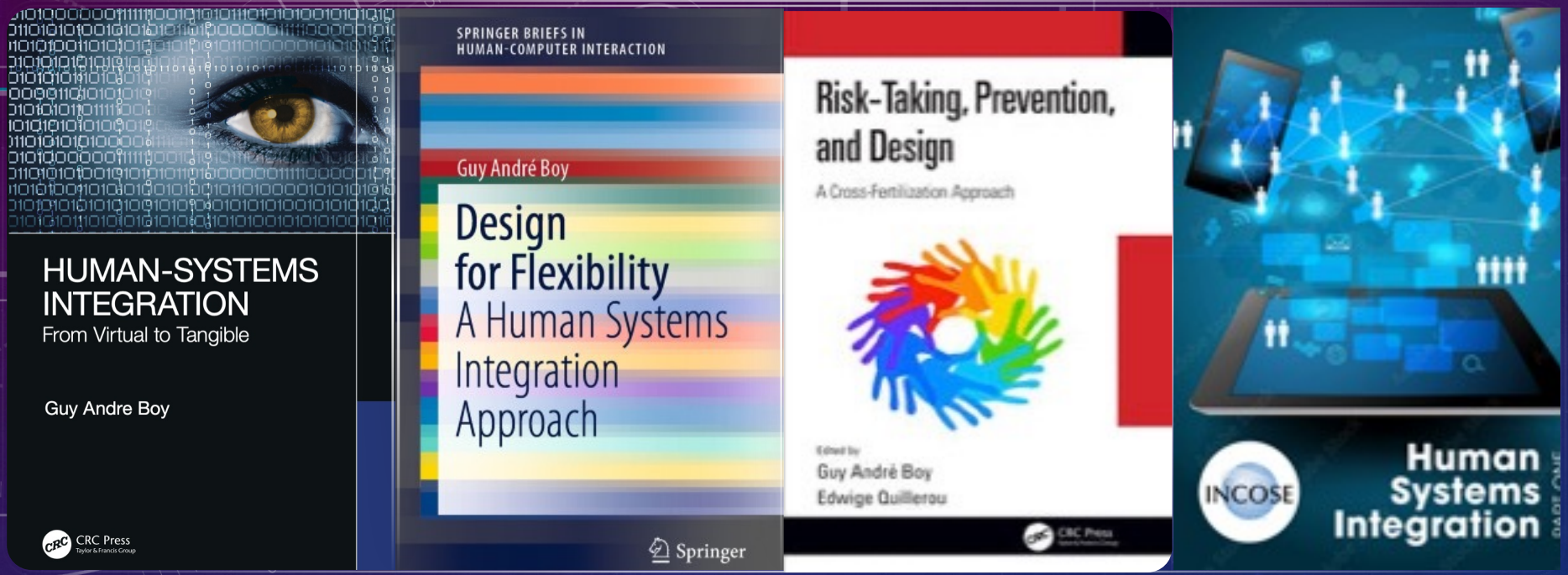
- Boy, G.A., Masson, D., Durnerin, E. & Morel C. (2024). PRODEC for Human Systems Integration of Increasingly Autonomous Systems. Systems Engineering Journal. Wiley, USA. DOI:10.1002/sys.21751.
- Boy, G.A. (2023). An epistemological approach to human systems integration. *Technology in Society Journal*, 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).



2020 2021 2022 2023

FOUR BOOKS

HANDBOOK OF SOCIOTECHNICAL SYSTEMS A HUMAN SYSTEMS INTEGRATION APPROACH

- To appear in 2025
- About 50 chapters (link)
- 16 countries

WHAT I PROPOSE FOR A FLEXTECH-2 CHAIR…

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Keep working with industry

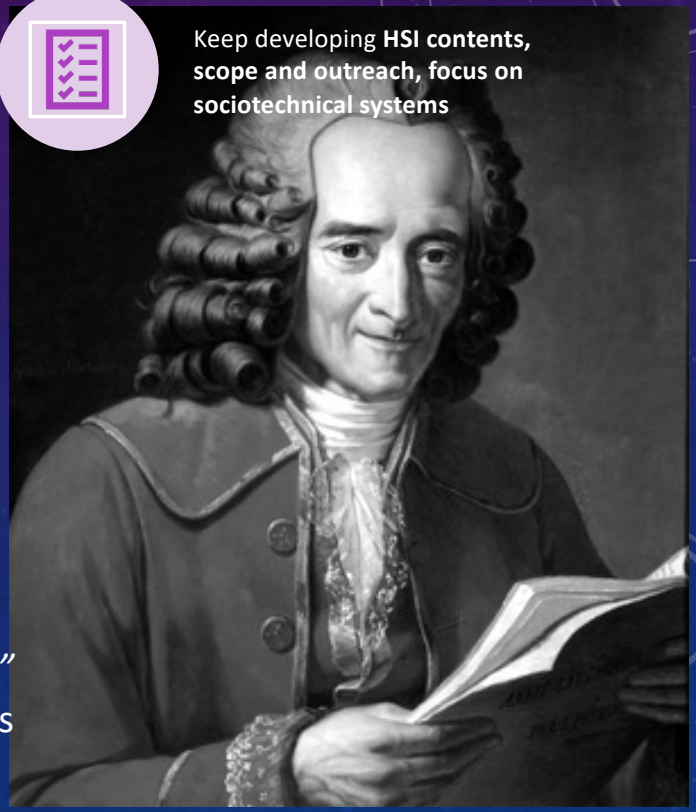
Keep developing **HSI training (face-to-face lectures, collaborative problem-solving, webinars, books, etc.)**

Keep developing **HSI contents, scope and outreach, focus on sociotechnical systems**

Further develop PRODEC (method & platform) and HSI more generally (ontology, models, etc.)

Further organize **international events (conferences, workshops)**

Work with complementary organizations (e.g., IEA, ACM)



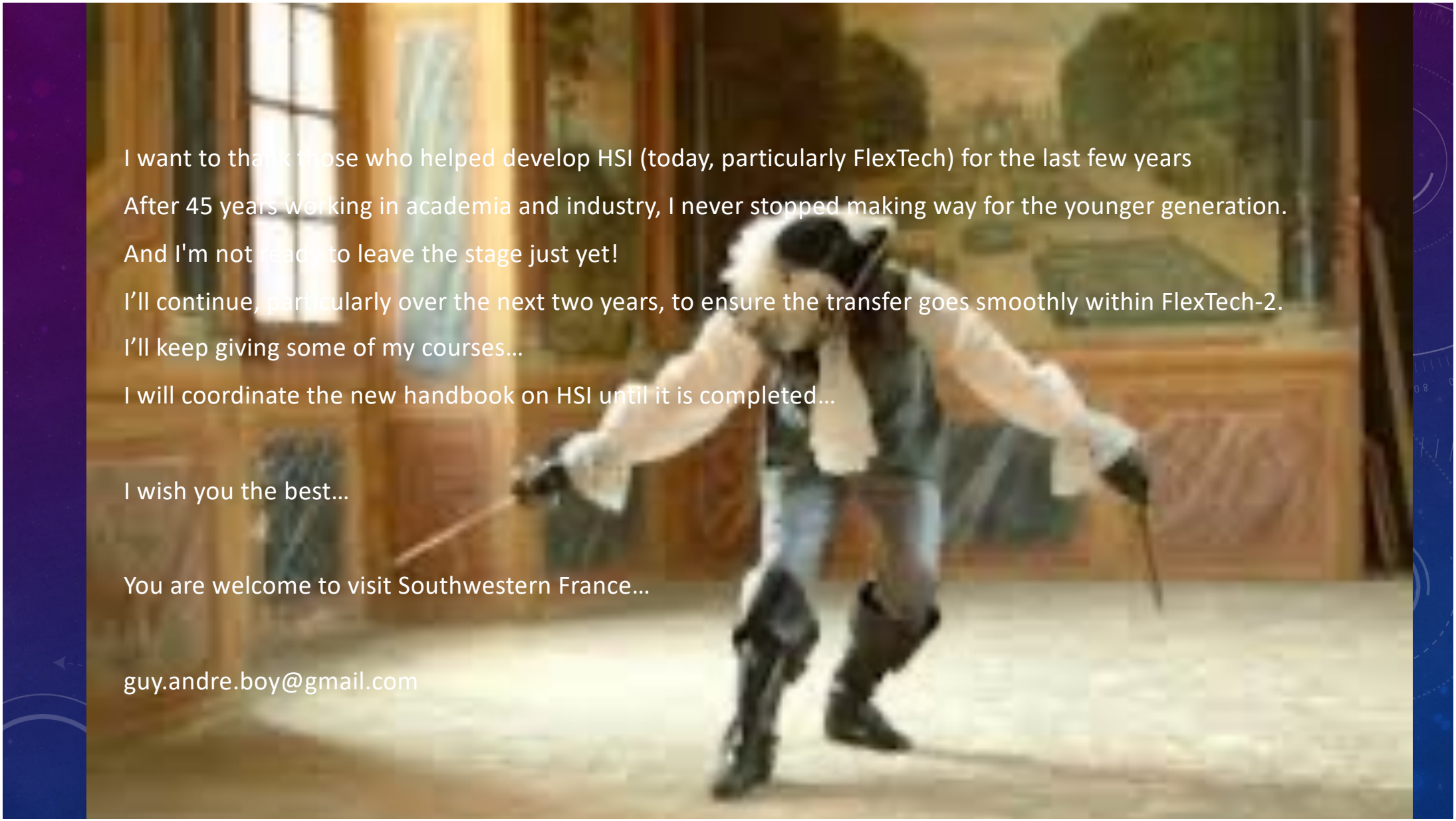
"Nothing can be done without a little enthusiasm."
Voltaire, Philosophical Letters

THREE OBJECTIVES FOR FLEXTECH-2

- **Industry 5.0**, which we prefer to call ‘Society 5.0’, i.e., taking people and organizations into account throughout the lifecycle of socio-technical systems (an approach advocated by the Horizon Europe program). We'll discuss the virtual and the tangible, human-in-the-loop modeling and simulation, digital twins, HSI ontology, expertise and creativity, and participatory design platforms.

- **Human-AI teaming**, i.e., taking into account HSI phenomena and metrics such as trust, collaboration, and operational performance in various contexts, particularly in supervision, mediation, and cooperation between highly computerized and interconnected human machines.

- **Socio-technical management of the unexpected**, i.e., the design, development, industrialization, and validation of technologies, new activities (specifically jobs), and organizations in a highly interconnected advanced digital industry.


I want to thank those who helped develop HSI (today, particularly FlexTech) for the last few years
After 45 years working in academia and industry, I never stopped making way for the younger generation.
And I'm not ready to leave the stage just yet!
I'll continue, particularly over the next two years, to ensure the transfer goes smoothly within FlexTech-2.
I'll keep giving some of my courses…
I will coordinate the new handbook on HSI until it is completed…
I wish you the best…
You are welcome to visit Southwestern France…
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