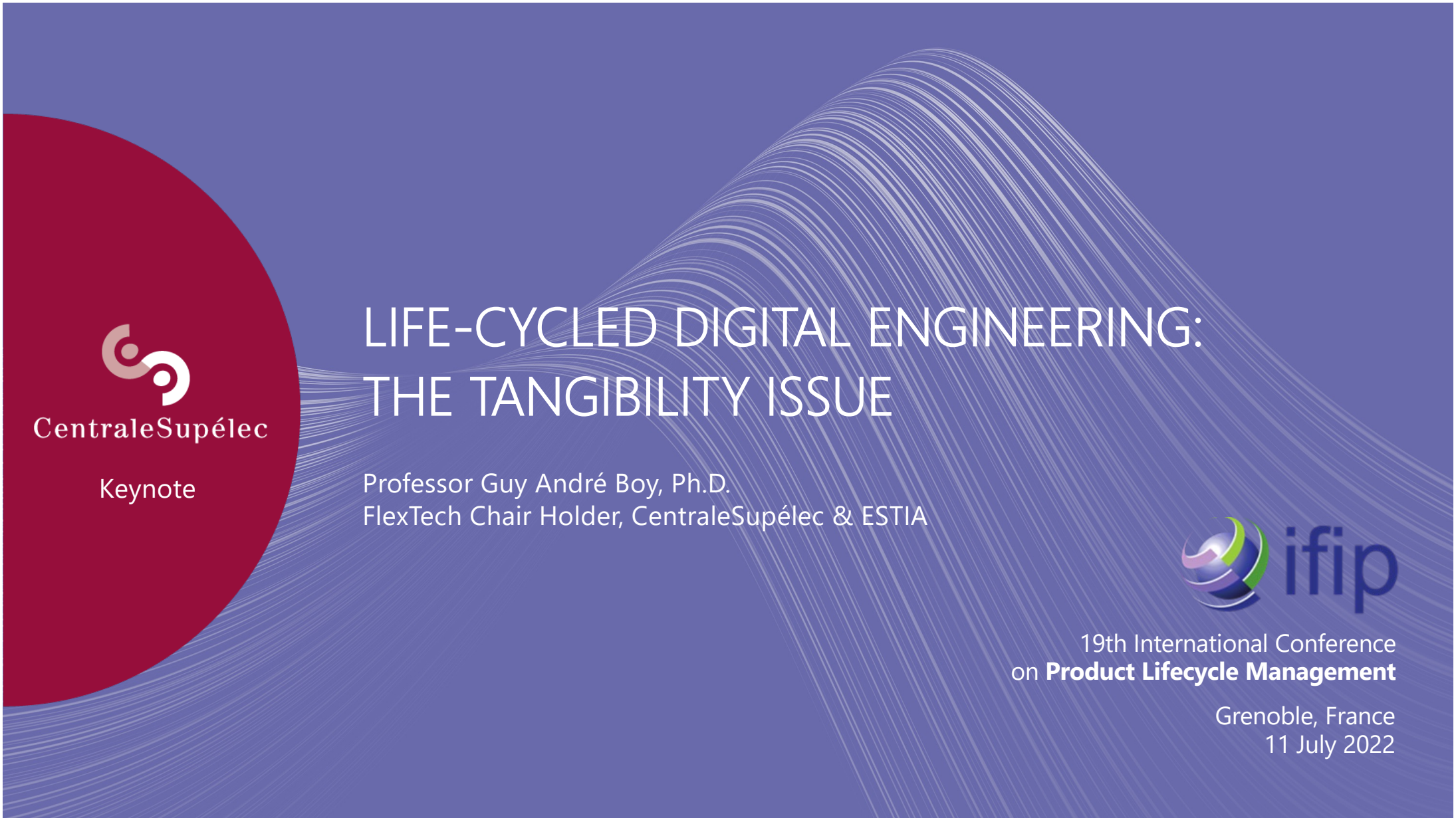
CentraleSupélec
Keynote
LIFE-CYCLED DIGITAL ENGINEERING:
THE TANGIBILITY ISSUE
Professor Guy André Boy, Ph.D.
FlexTech Chair Holder, CentraleSupélec & ESTIA
ifip
19th International Conference
on Product Lifecycle Management
Grenoble, France
11 July 2022

TANGIBILITY…

Physical tangibility
e.g., I grab a pen

Figurative (or cognitive) tangibility
e.g., I grab a concept


1. We inverted the hardware-software dependency
2. We are starting to consider unexpected events
3. We start to understand flexibility & autonomy better
4. We are no longer in the single agent-based engineering era
5. We are complexifying our sociotechnical world everyday
6. We are making human systems integration a discipline
WHY IS TANGIBILITY SO IMPORTANT TODAY?
I will now develop these six points…

TANGIBILITY ISSUES EMERGE FROM VIRTUAL HUMAN-CENTERED DESIGN

1

FROM HARDWARE TO SOFTWARE

20th Century

Automation & HCI

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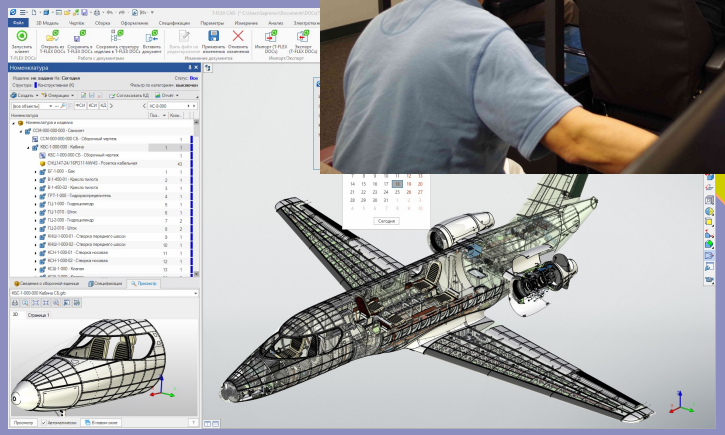
FROM SOFTWARE TO HARDWARE



21th Century

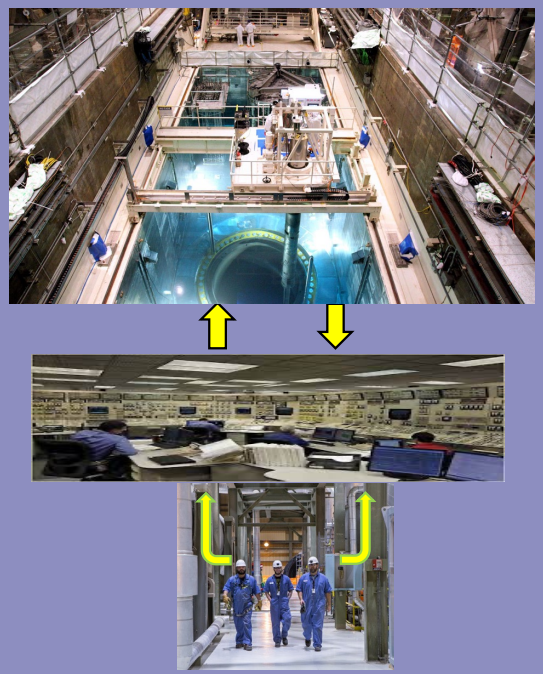
Tangibility & Flexibility

FROM MEANS TO PURPOSE

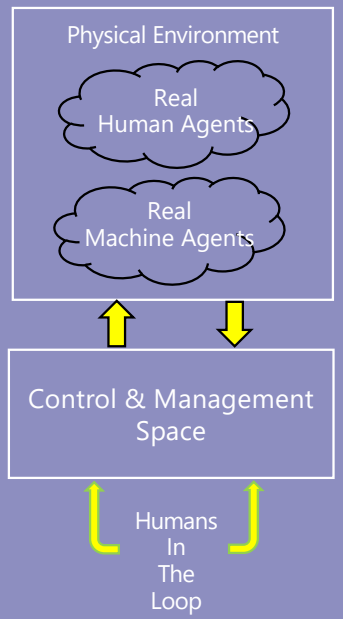
Engineering

Ergonomics
Automation

Human
Factors



Tangible
Human-Centered Engineering

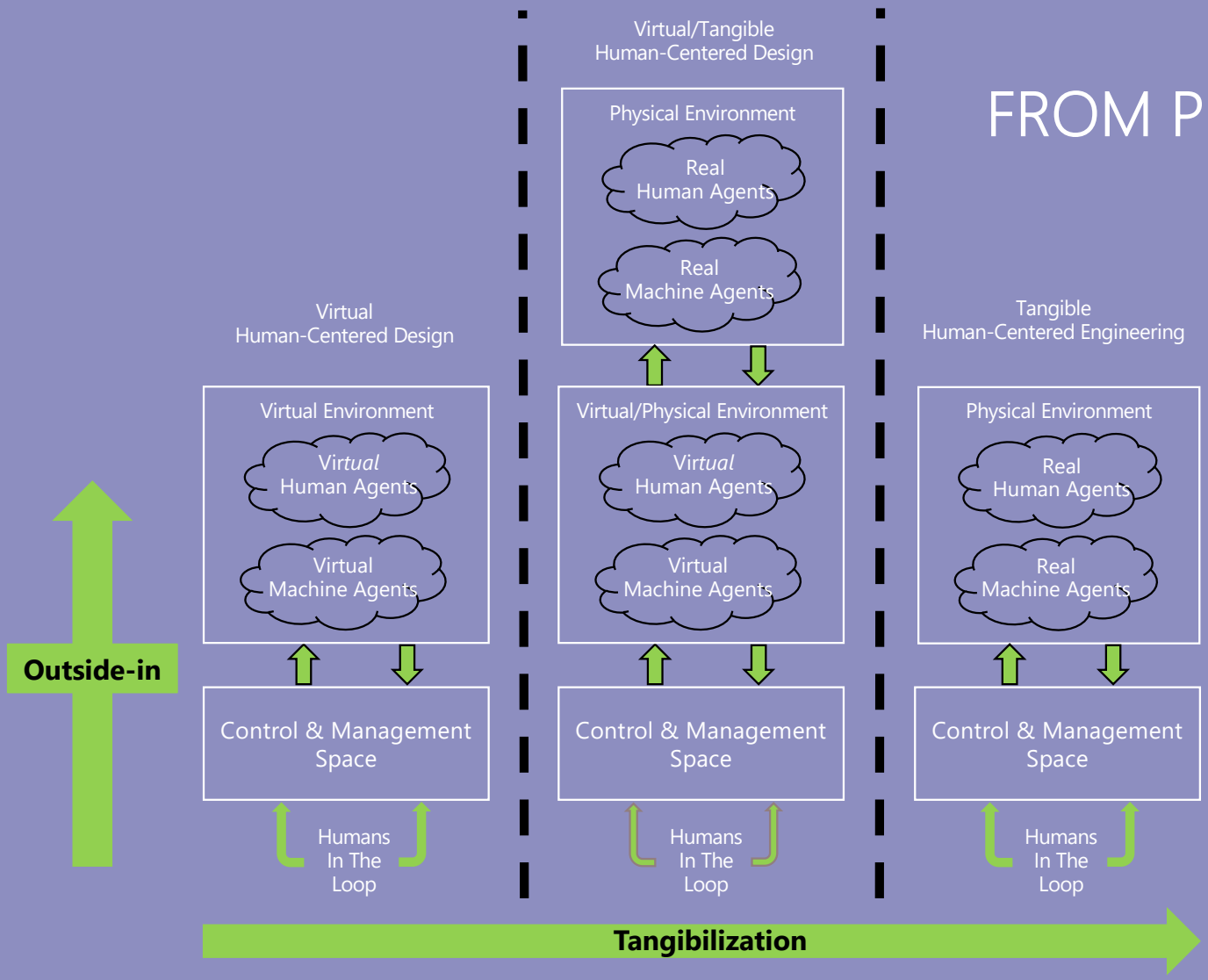


Inside-out

20th century approach

Engineering,
Ergonomics,
HCI &
Automation

FROM PURPOSE TO MEANS



21st century approach

HSI

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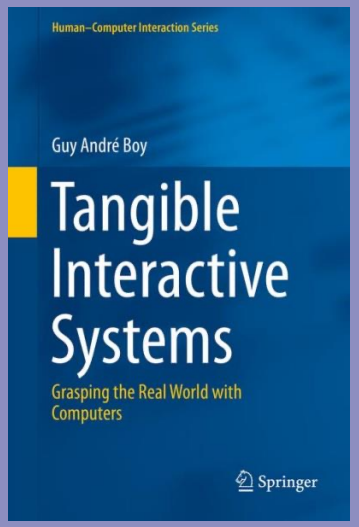
TANGIBILITY: SYSTEMIC ATTRIBUTES

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

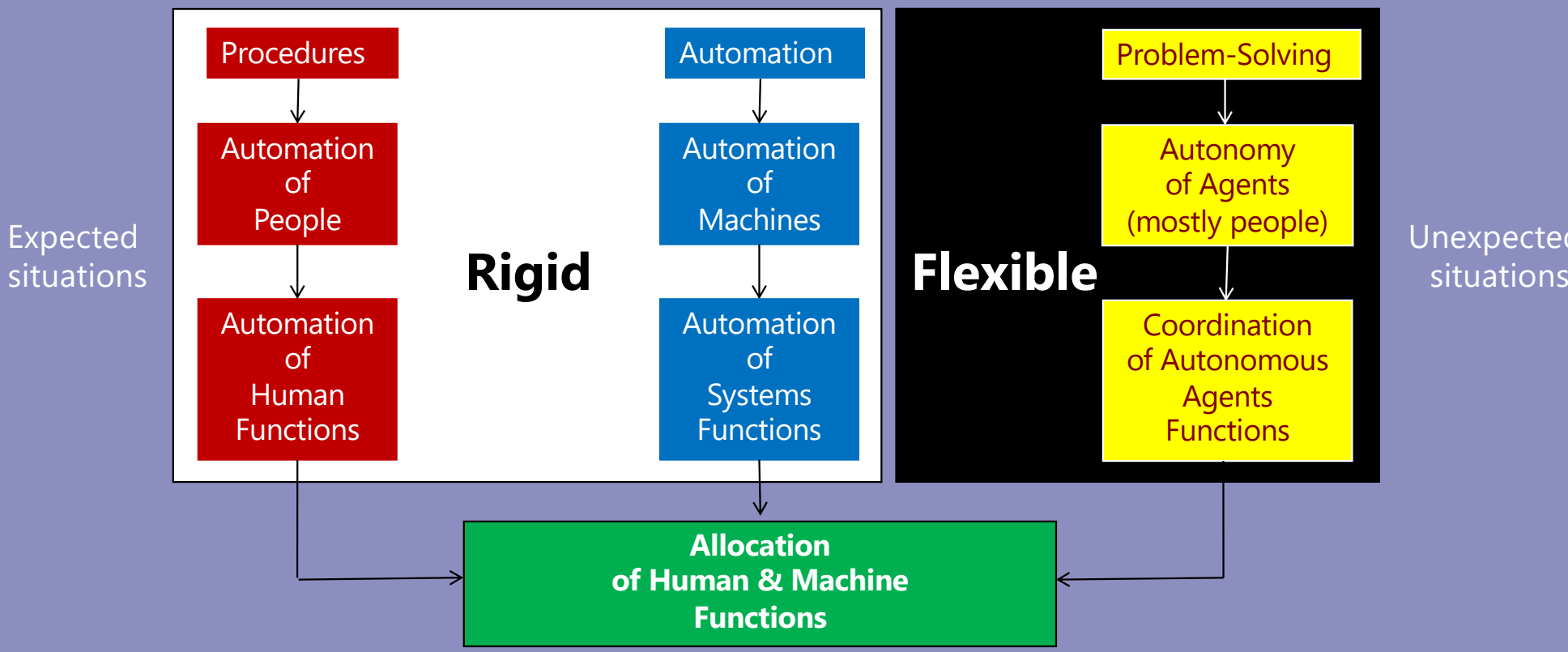
+ Social Factors → Shared situation awareness
Cooperative decision-making
Harmonized risk taking
Trust and collaboration



TANGIBLE SOLUTIONS
ARE REQUIRED
TO HANDLE
UNEXPECTED SITUATIONS

2

FROM RIGID AUTOMATION TO FLEXIBLE AUTONOMY



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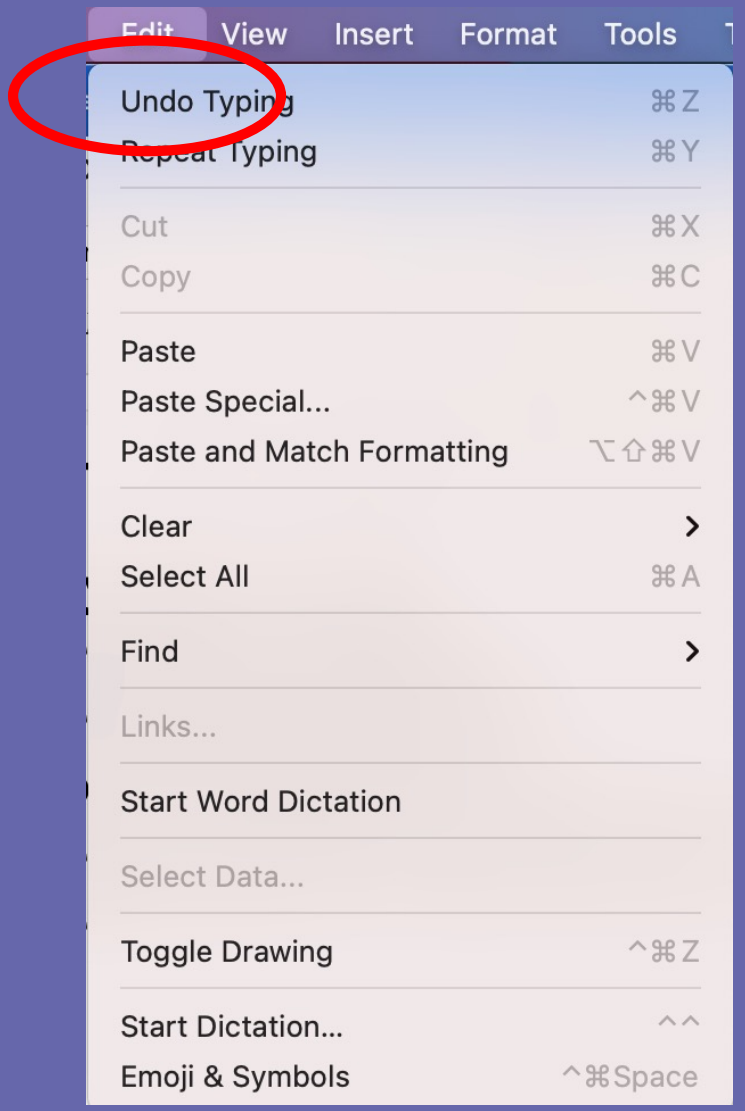
FLEXTECH

Design for Flexibility

What kind of support?

technology



APOLLO 13 CO_2 …

FLEXTECH

Design for Flexibility

What kind of support?

organization

… collaborative problem solving!

FLEXTECH

Design for Flexibility

What kind of support?

competences

FLEXTECH

Technology

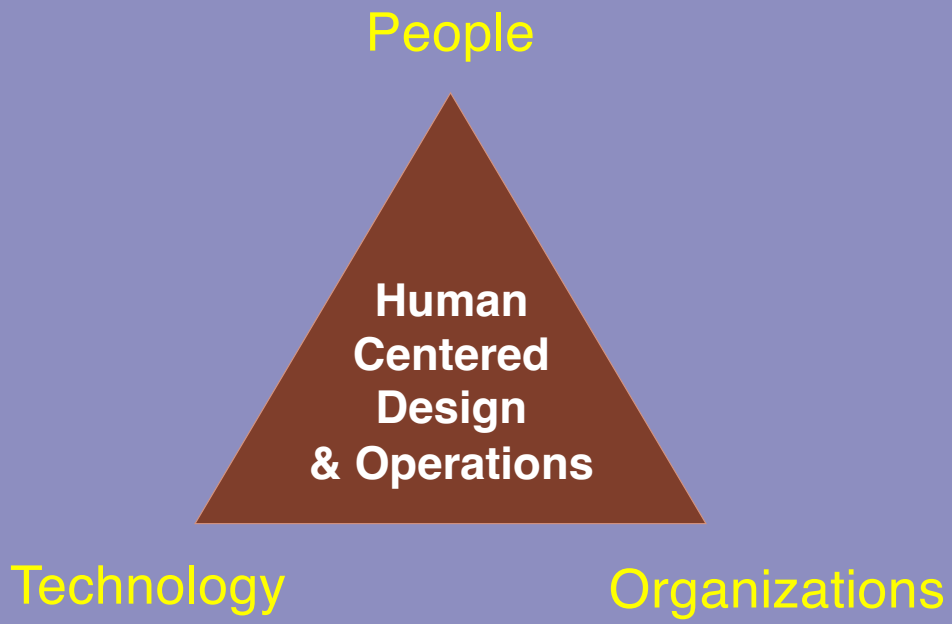
- Problem-solving tool support
- e.g., undo

Organization

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

People

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



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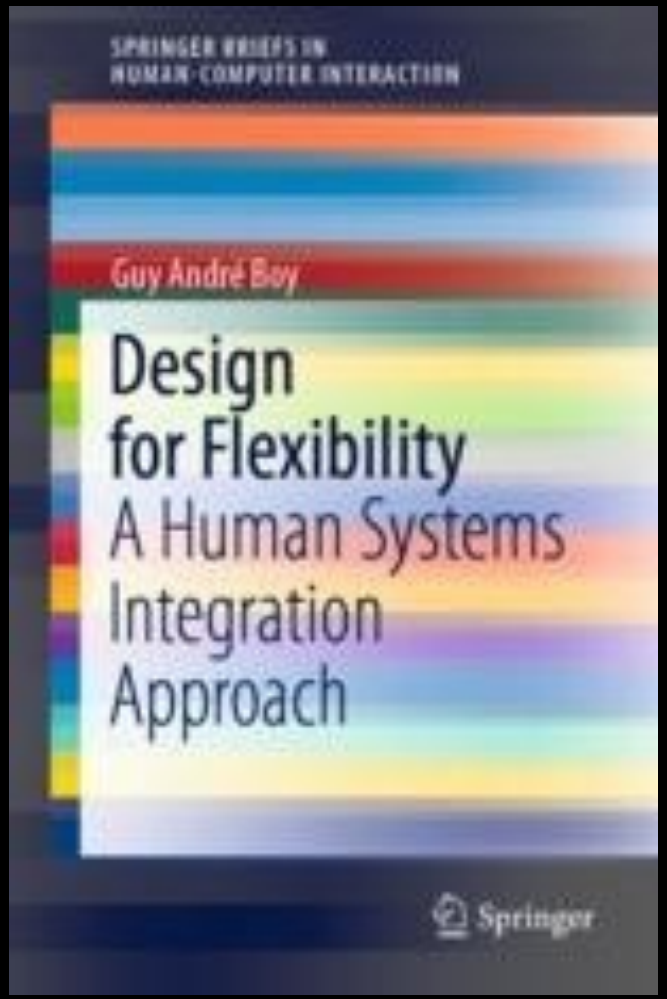
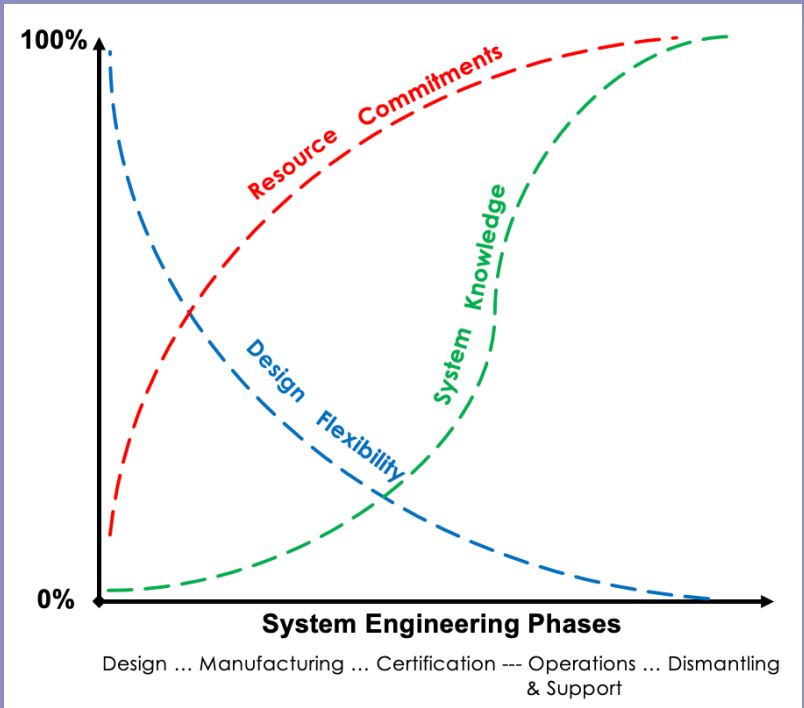
TANGIBILITY
IS STRONGLY
RELATED TO FLEXIBILITY

3

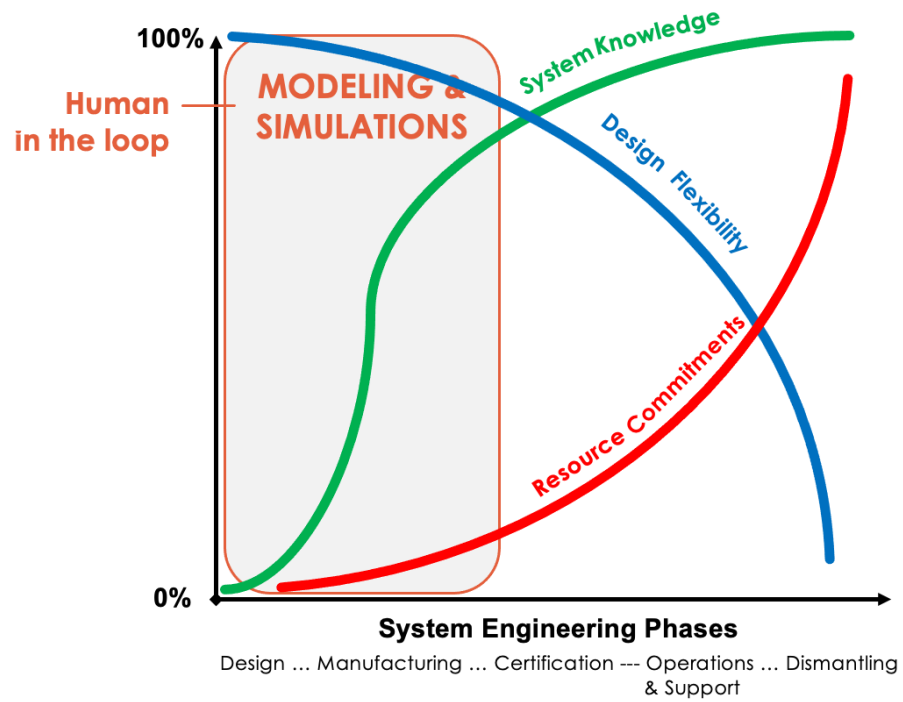


LIFE-CYCLED HUMAN SYSTEMS INTEGRATION

Technology-centered



Human-centered



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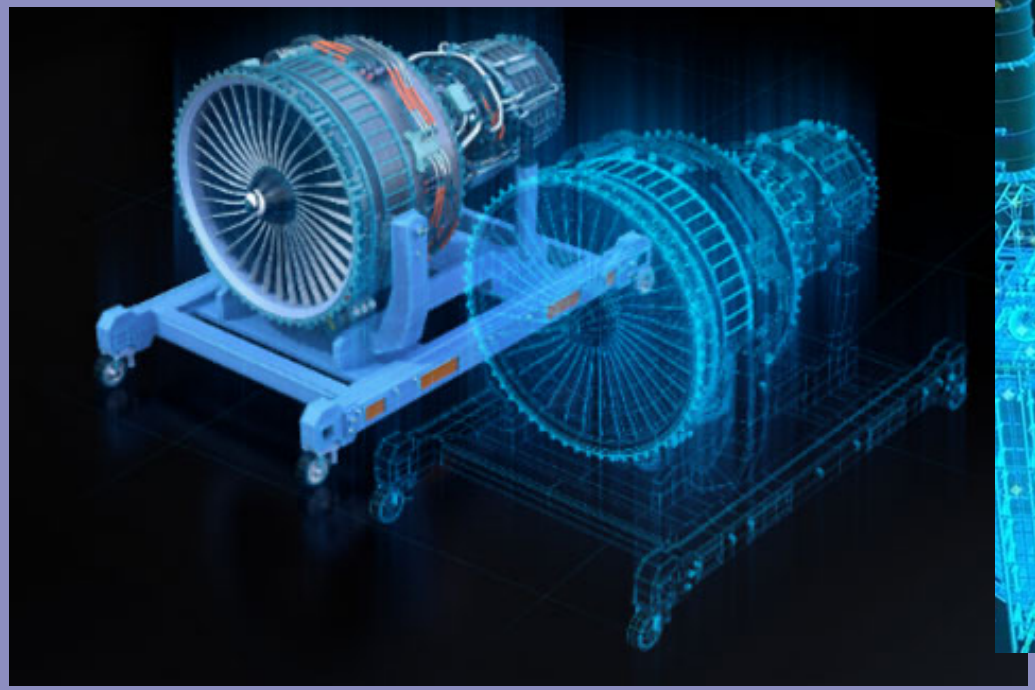
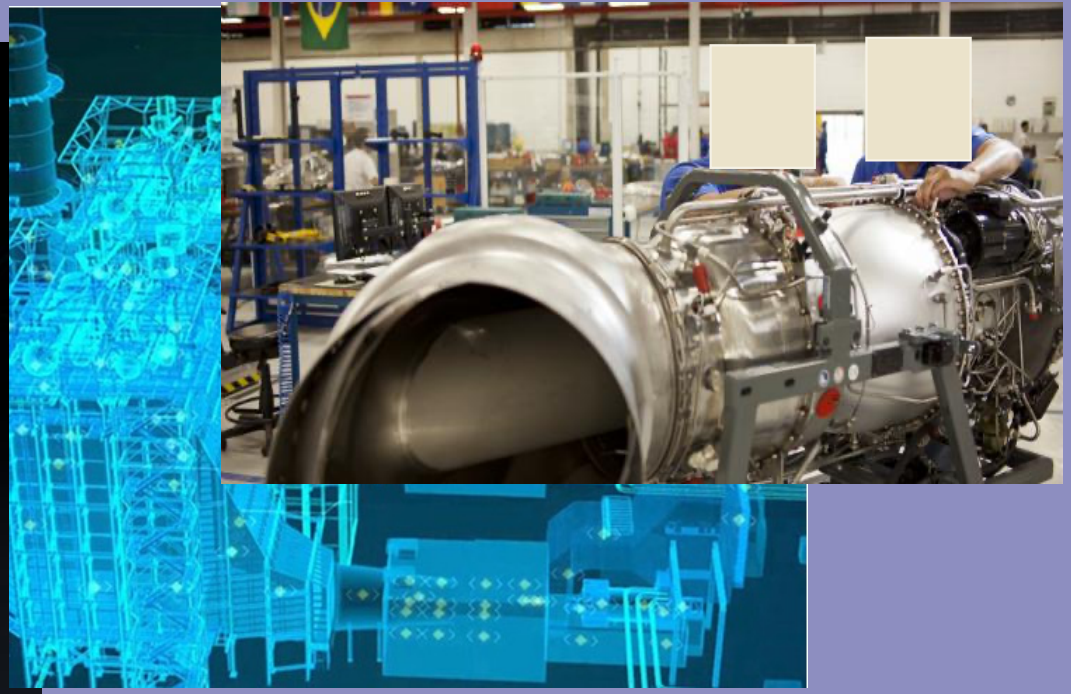
HUMAN-CENTERED DESIGN OF A DIGITAL TWIN FOR HELICOPTER ENGINE MAINTENANCE



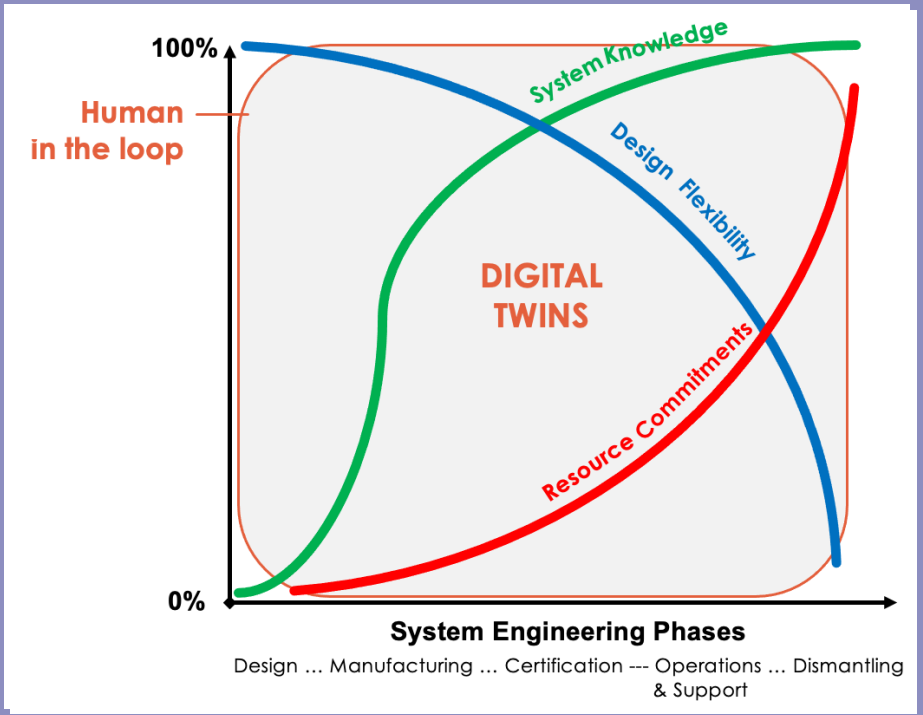


DIGITAL TWINS

Expanding HITLS
- During the whole life cycle
- "what if?"

Vivid documentation → MBSE
- Integration of experience feedback
- Organizational memory

DTs as virtual assistants → HAT
- Multi-agent collaboration
- Mediators for collaborative work

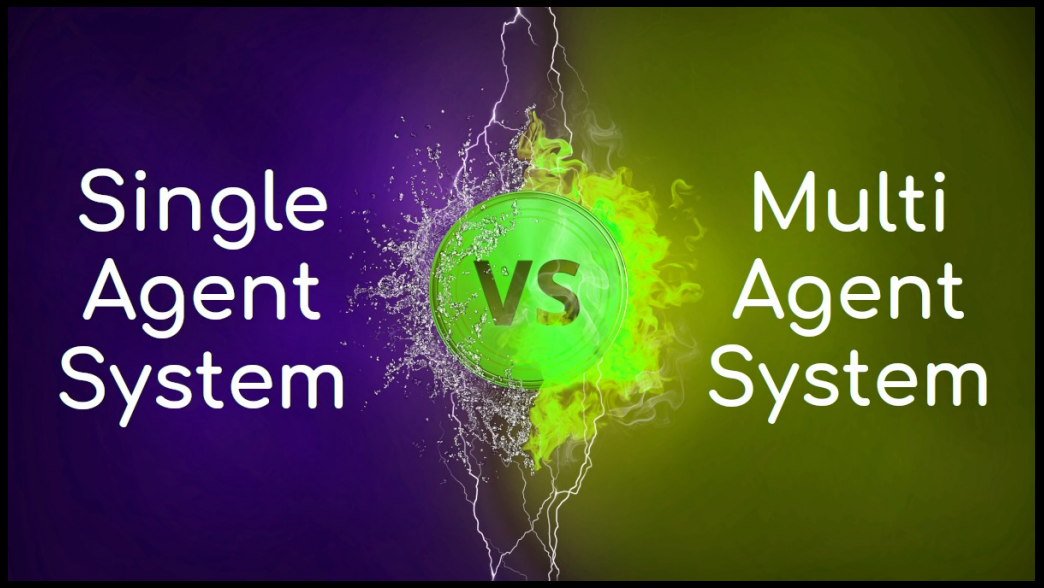


MBSE: Model-Based Systems Engineering
HAT: Human Autonomy Teaming

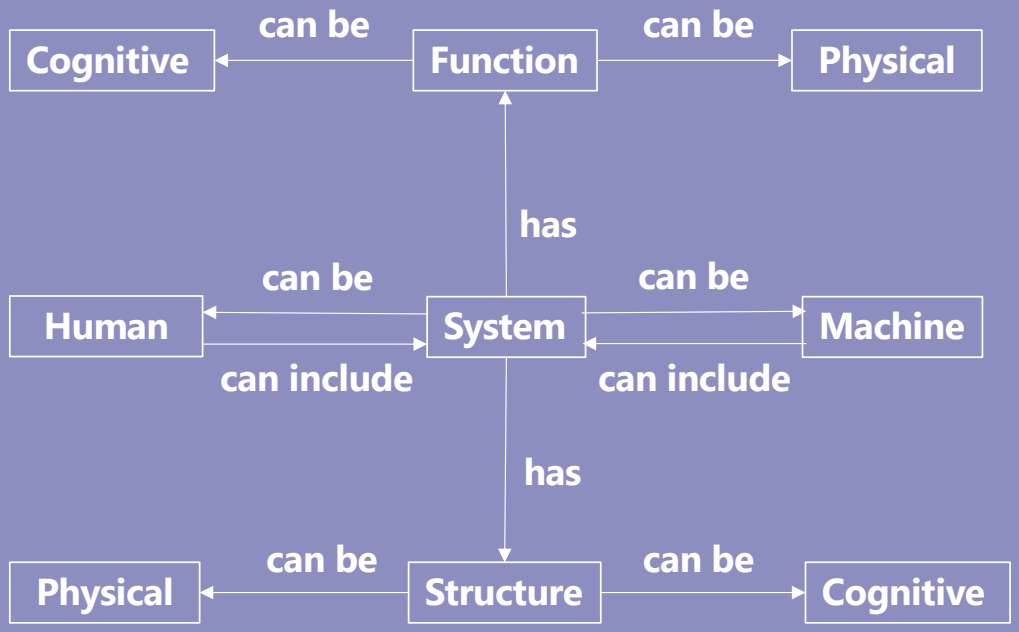

1. We inverted the hardware-software dependency
2. We are starting to consider unexpected events
3. We start to understand flexibility & autonomy better
4. We are no longer in the single agent-based engineering era
5. We are complexifying our sociotechnical world everyday
6. We are making human systems integration a discipline
WHY IS TANGIBILITY SO IMPORTANT TODAY?
I will now develop the last three points…

TANGIBILITY REQUIRES AN APPROPRIATE SYSTEMIC ONTOLOGY

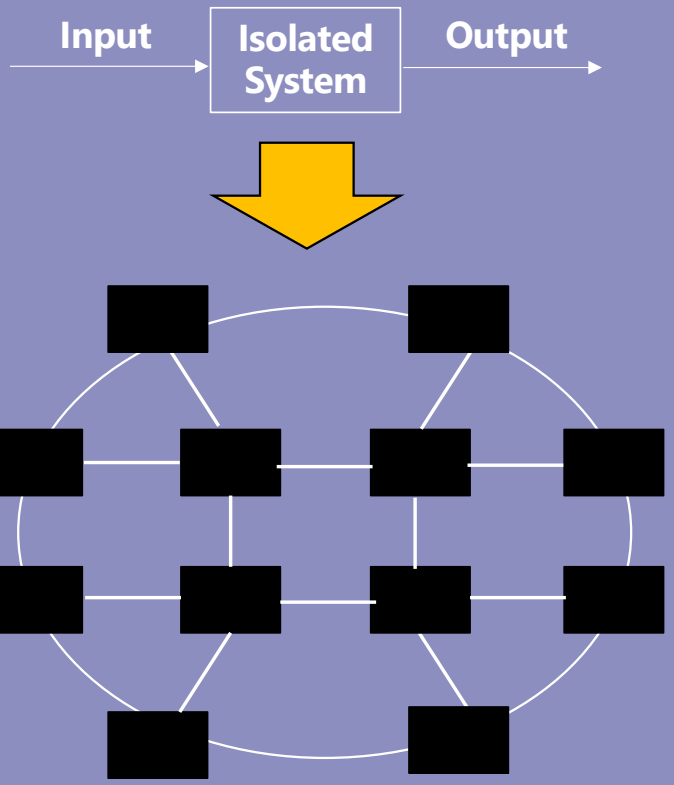
4



WHAT IS A SYSTEM?



Systems include Humans and Machines…



Interconnected System of Systems

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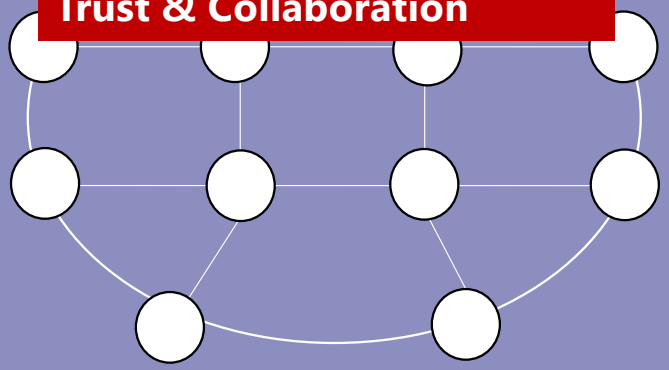
SYSTEM = FUNCTION + STRUCTURE

Shared situation awareness
Speed & precision
Resilience
Trust & Collaboration

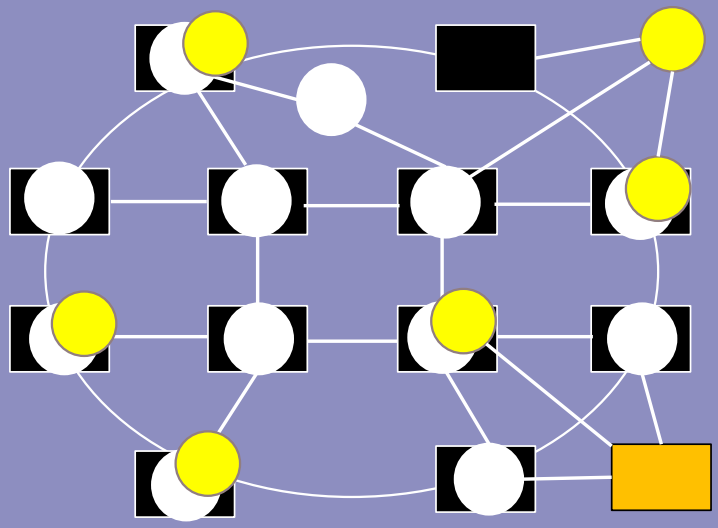


Interconnected Functions of Functions

Emergent Structures

Emergent Functions

Overlapping Functions of Functions



Interconnected Structures of Structures

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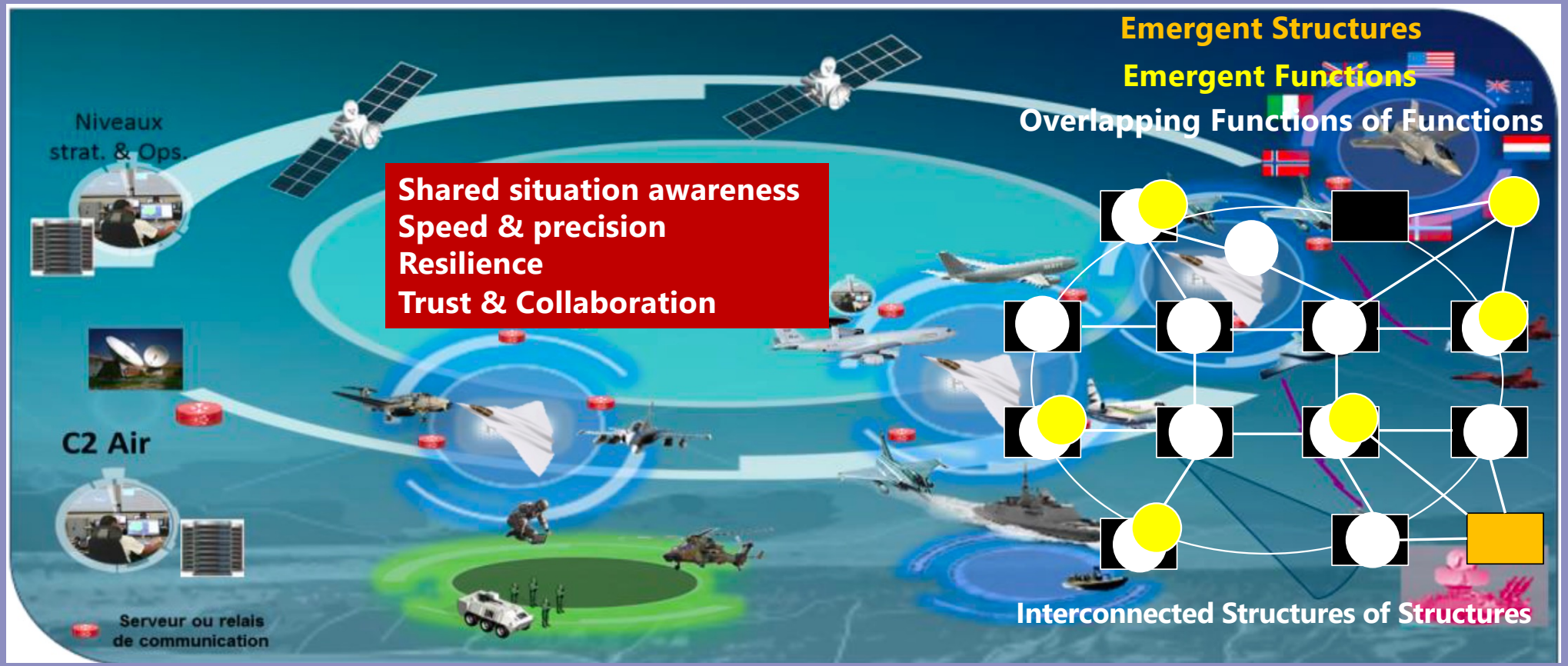
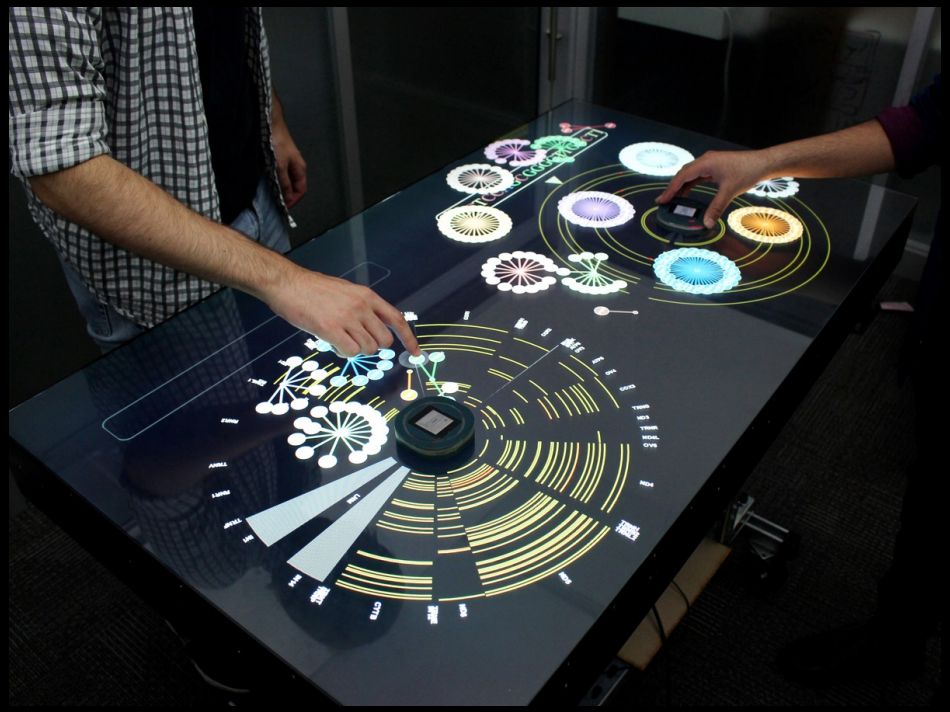
SYSTEM = FUNCTION + STRUCTURE

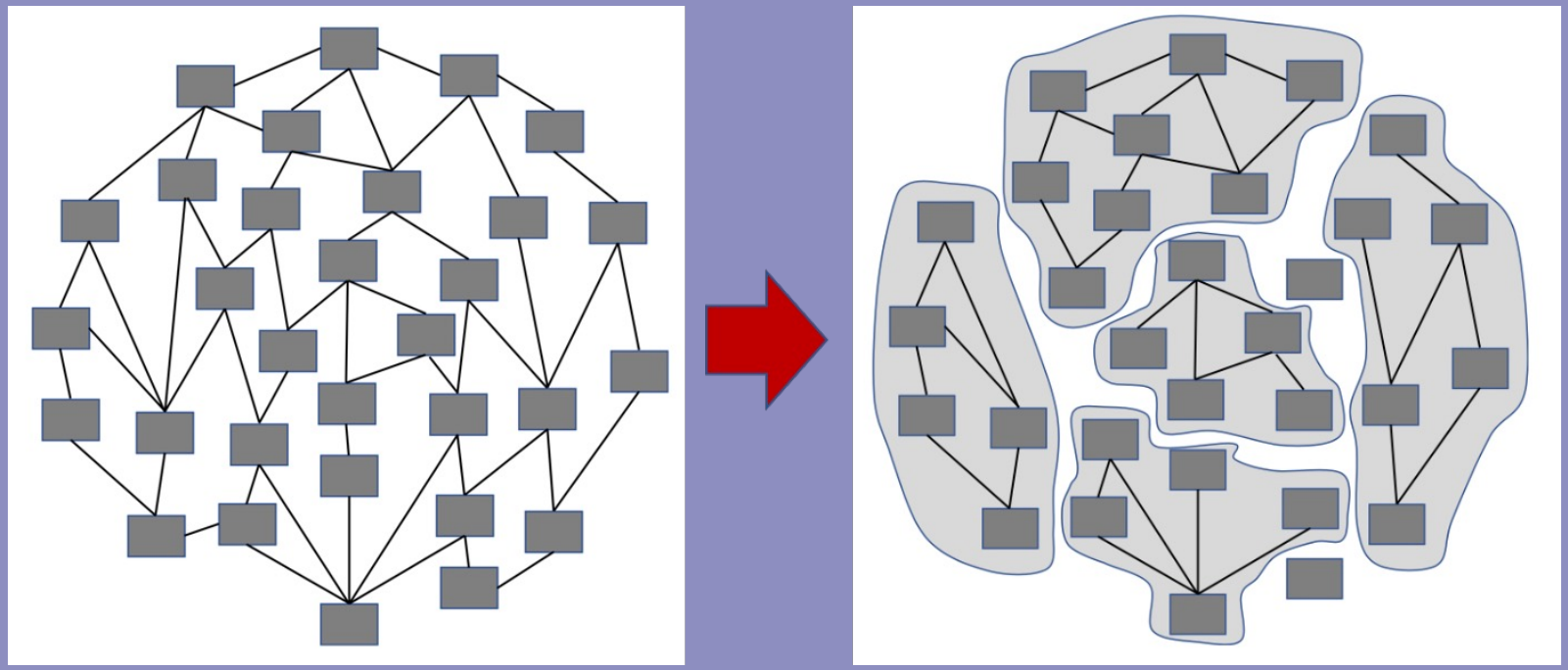


TALKING ABOUT TANGIBILITY IS MAKING SENSE OF COMPLEXITY

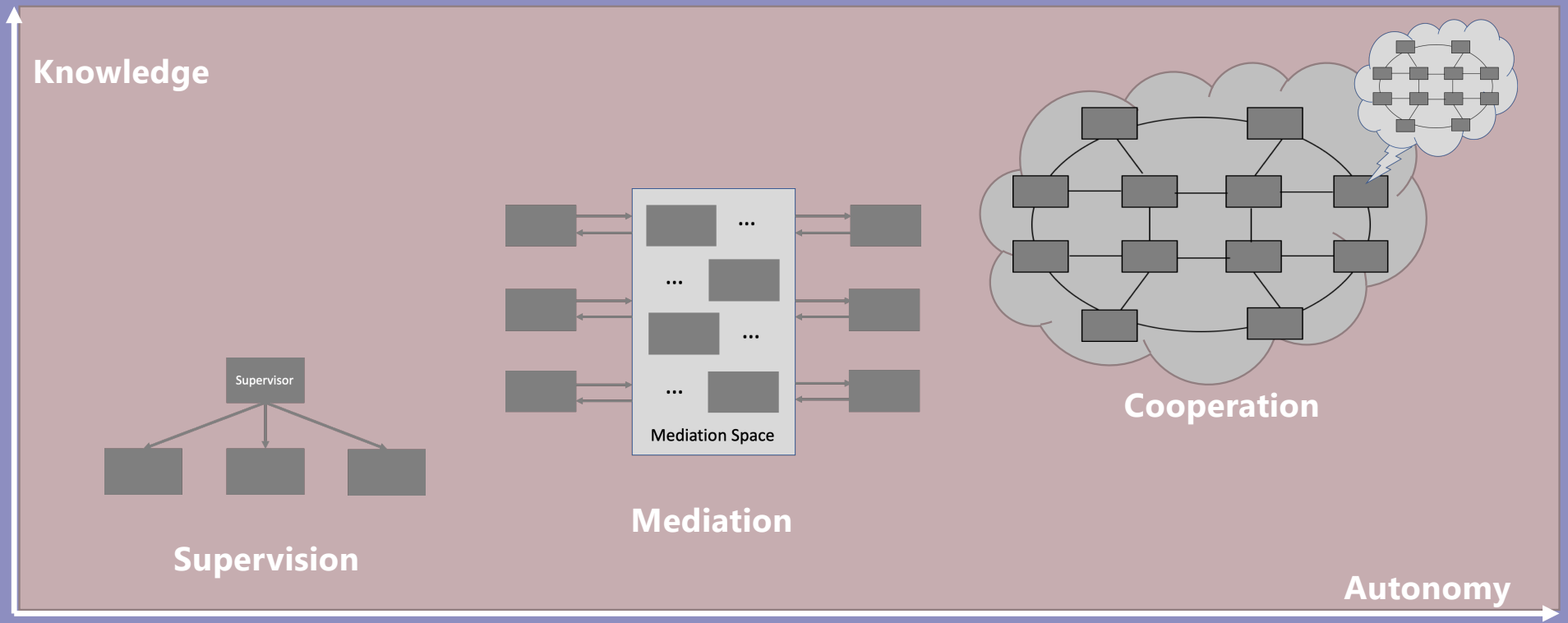
5



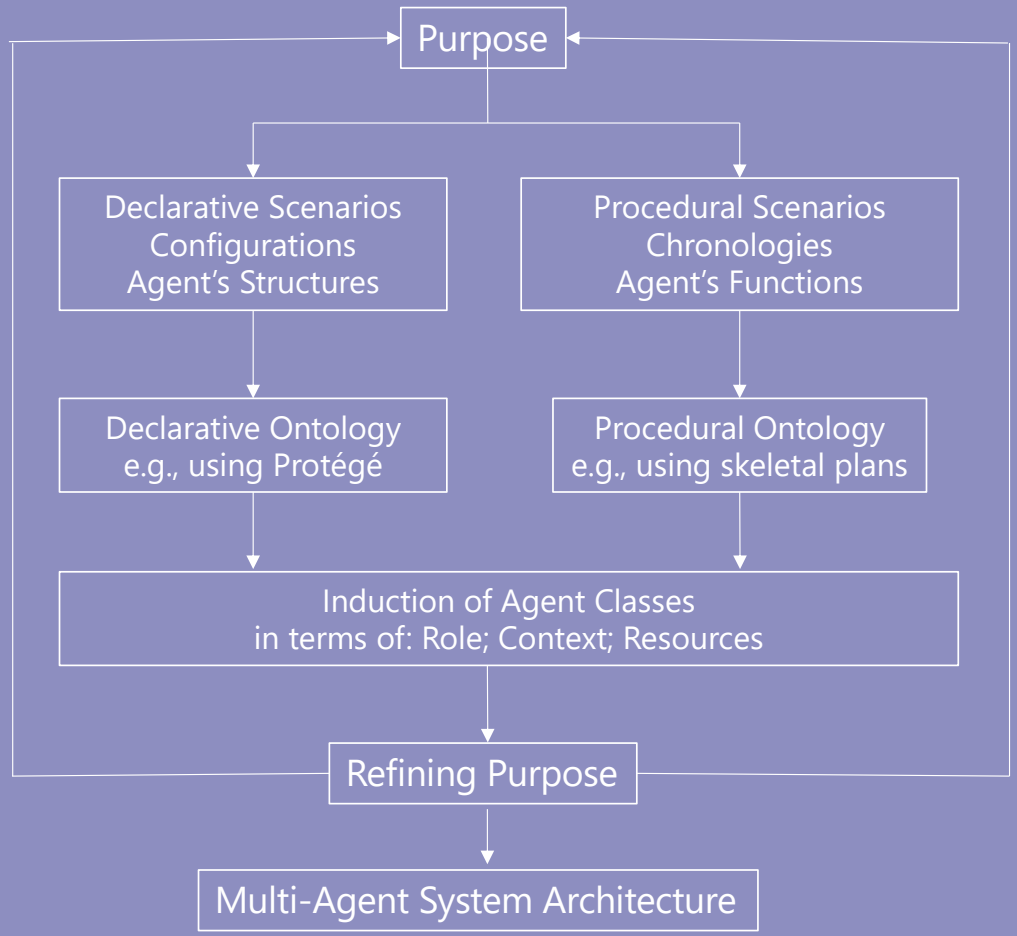
SEPARABILITY



SYSTEMIC INTERACTION MODELS…
… AND AUTHORITY SHARING



SCENARIO-BASED DESIGN + HUMAN-IN-THE-LOOP SIMULATION



What do we want to do?

Analysis of the existing so far…

Anticipating possible futures…

Making a Multi-Agent Ontology

Becoming more generic…

PRODEC

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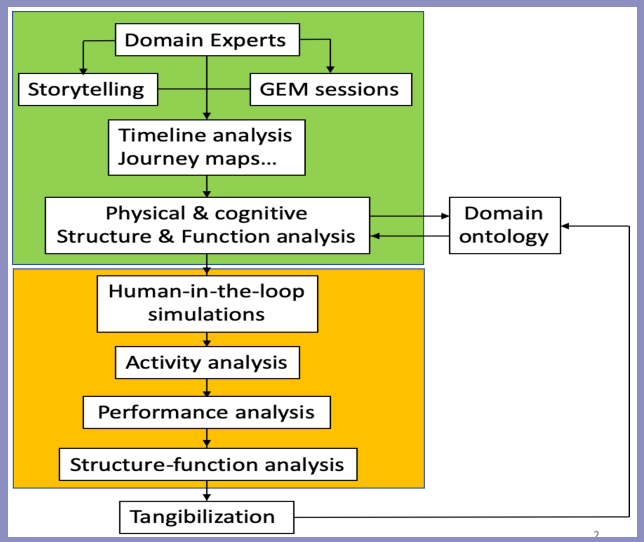
OFF-SHORE OIL & GAS MULTI-AGENT TELEROBOTIC SYSTEMS

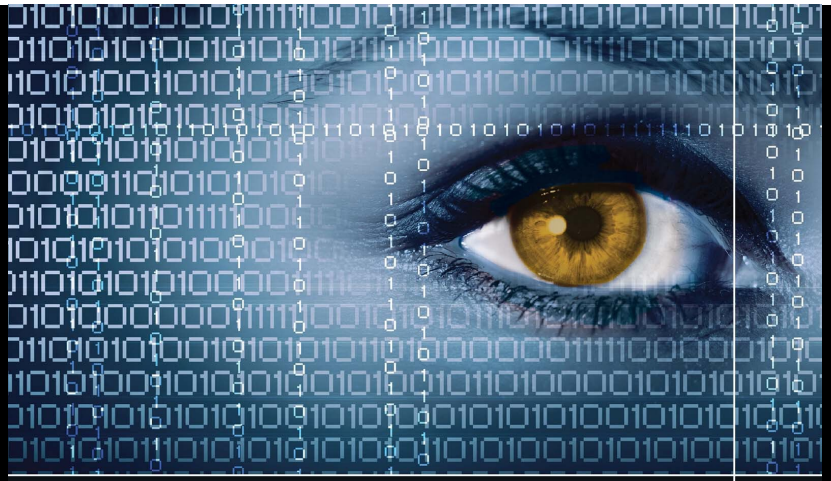
Using PRODEC method combined with HITLS



Tangibilization

TOWARD A NEW DISCIPLINE...

6



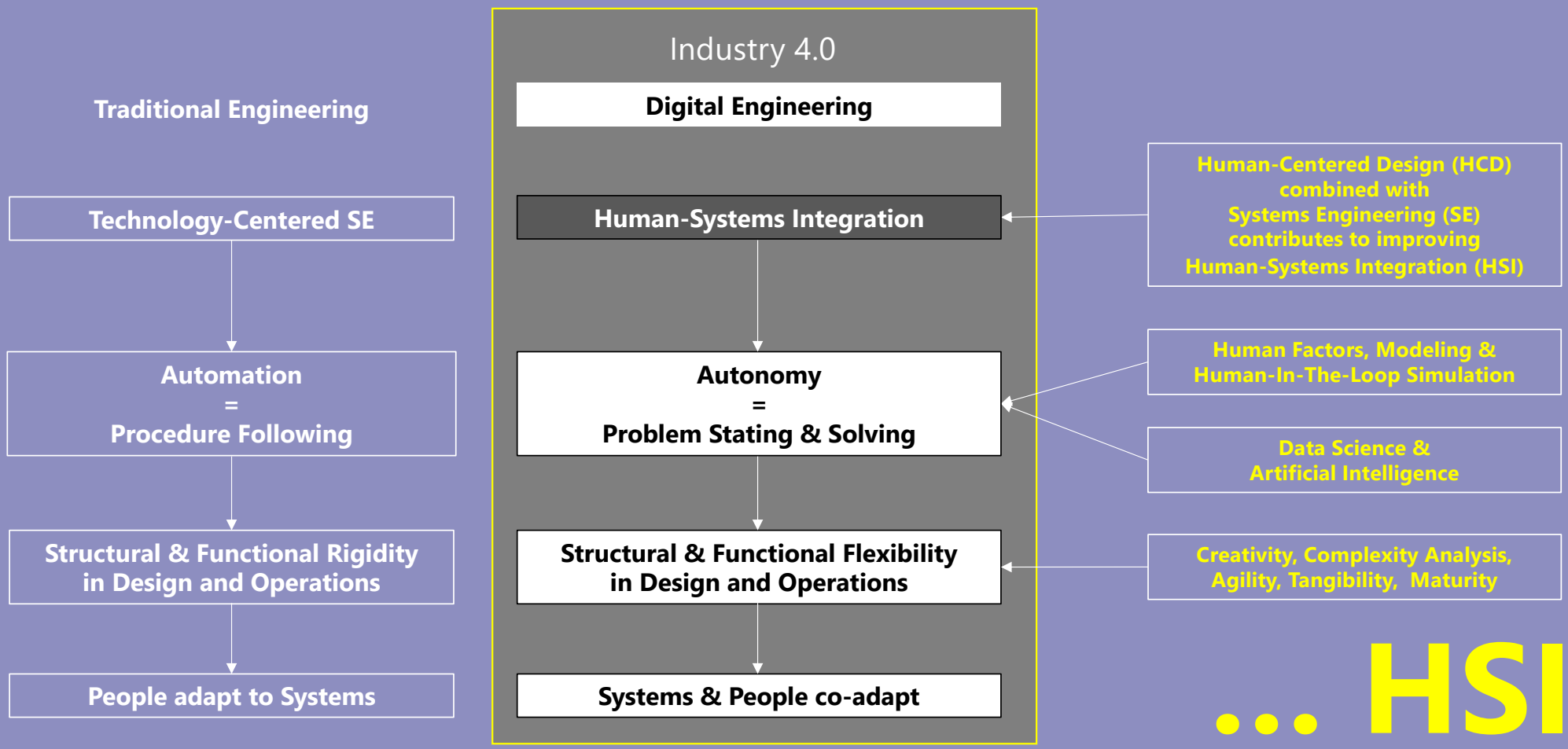
HUMAN–SYSTEMS INTEGRATION

From Virtual to Tangible

Guy André Boy

CRC Press
Taylor & Francis Group

TOWARD MORE AUTONOMY & FLEXIBILITY…



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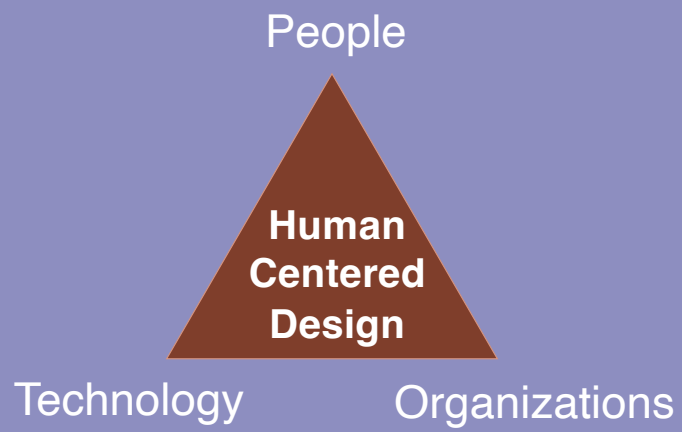
INCREMENTAL ADAPTATION

- Technological adaptation
- Organizational adaptation
- People adaptation



MATURITY

READINESS LEVELS

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READINESS LEVELS

Technology

Human

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

Organizations

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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CONCLUDING…

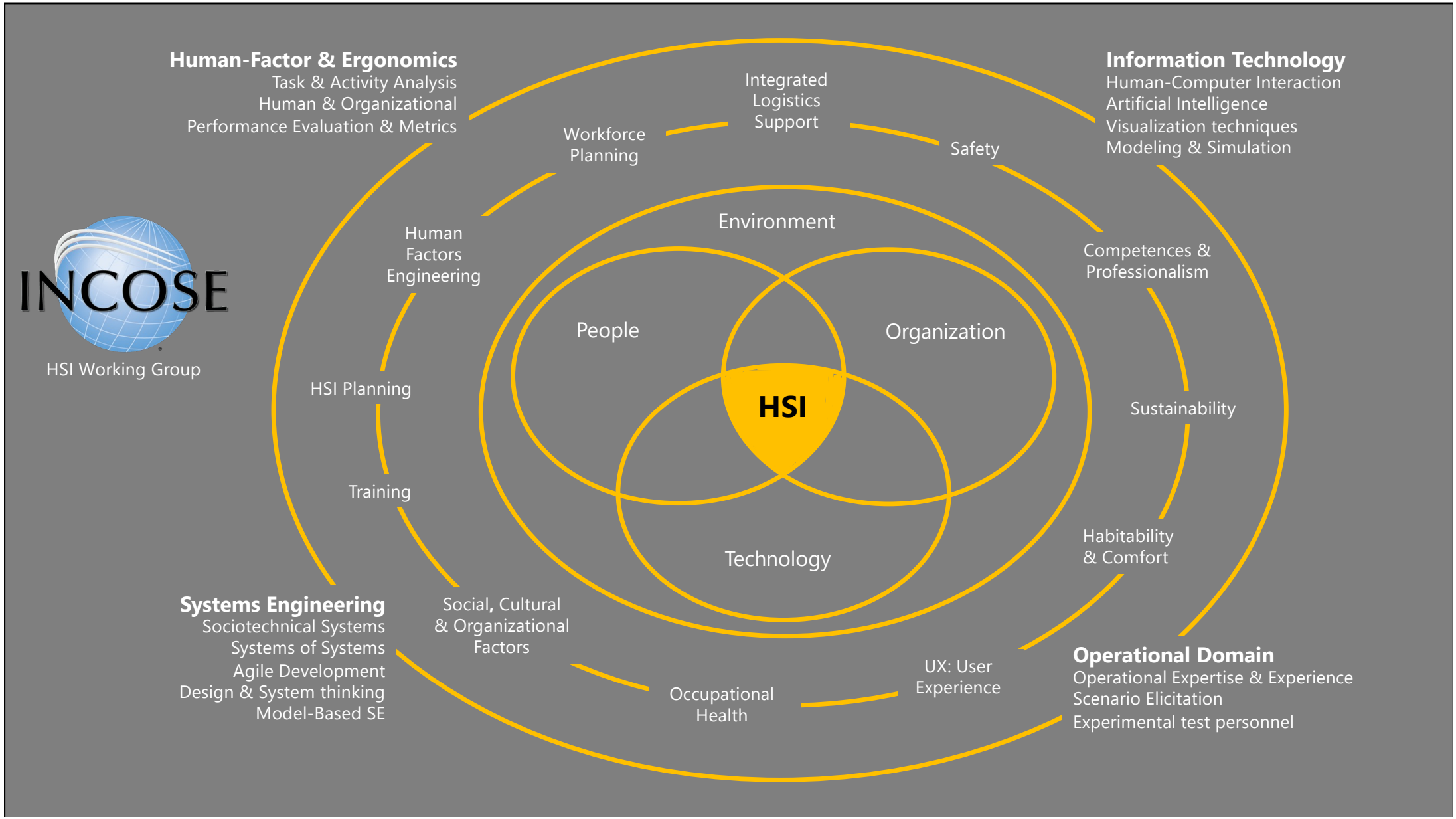
Awareness of the various possible contexts!

- scenarios
- human-in-the-loop simulations
- elicitation of emergent cognitive functions

Scenario-based design → solid conceptual models

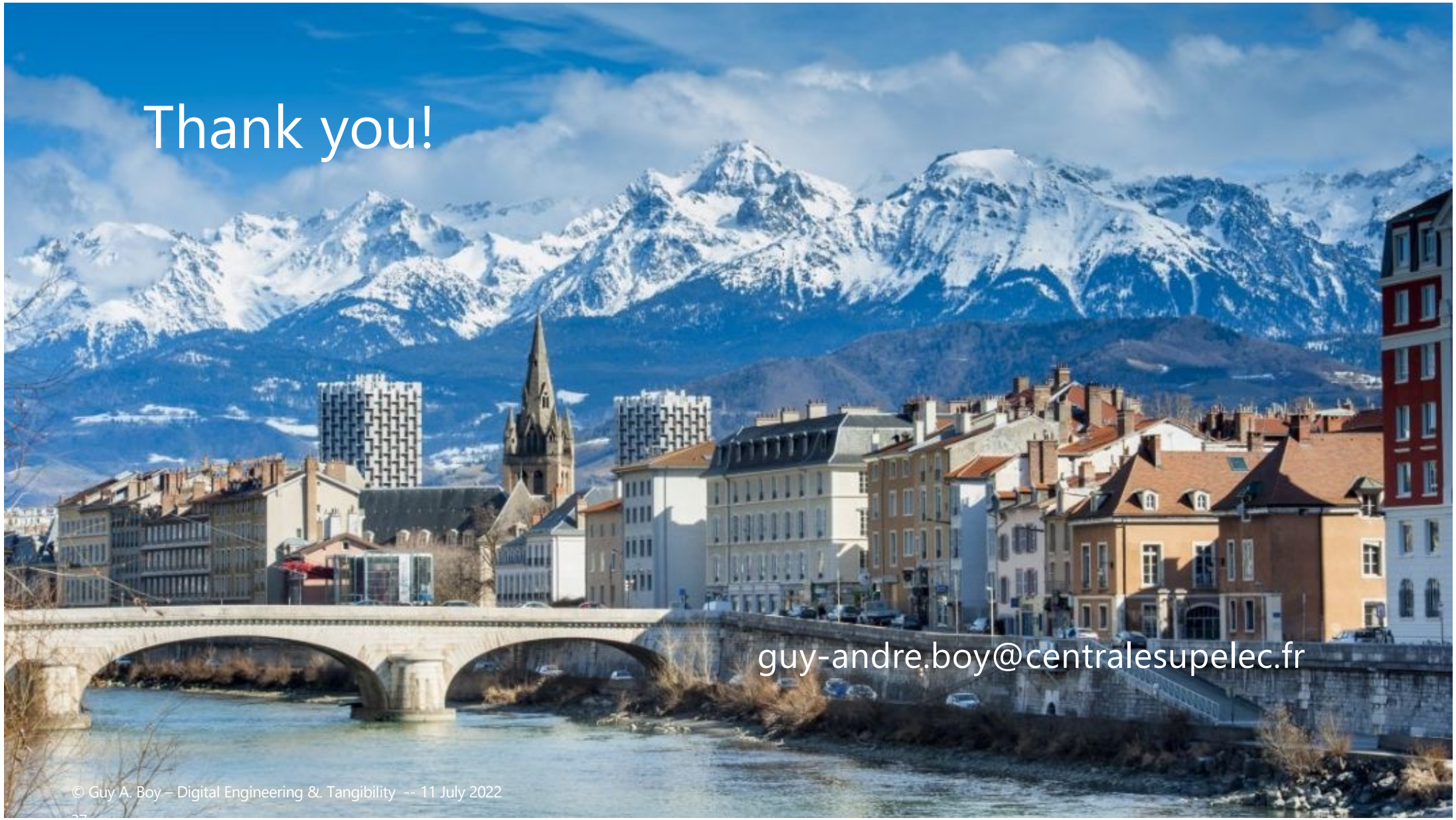
Orchestra Model pour design, evaluation and operations

- Music theory → common framework (interaction models)
- Composers → scores = contracts + coordination
- Conductors → dynamic re-allocation
- Musicians → **competence + engagement + cooperation**
- Audience → constant communication and education


Human-Factor & Ergonomics
Task & Activity Analysis
Human & Organizational
Performance Evaluation & Metrics
Information Technology
Human-Computer Interaction
Artificial Intelligence
Visualization techniques
Modeling & Simulation
INCOSE
HSI Working Group
Integrated Logistics Support
Workforce Planning
Safety
Human Factors Engineering
Environment
Competences & Professionalism
People
Organization
HSI Planning
HSI
Sustainability
Training
Habitability & Comfort
Technology
Systems Engineering
Sociotechnical Systems
Systems of Systems
Agile Development
Design & System thinking
Model-Based SE
Social, Cultural & Organizational Factors
UX: User Experience
Occupational Health
Operational Domain
Operational Expertise & Experience
Scenario Elicitation
Experimental test personnel

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 **Openness**, **Education**, **Empathy** and **Enthusiasm**!


Thank you!
guy-andre.boy@centralesupelec.fr