SCENARIO-BASED DESIGN:

LOOKING FOR THE RIGHT MIX OF PROCEDURAL AND DECLARATIVE KNOWLEDGE

PROF. GUY ANDRÉ BOY

THE BASIC IDEA

- Descriptions of people using technology
- Discussing and analyzing how technology is (or could be) used to reshape their activities
- Early stages of design process

Scenario-Based Design
is a family of techniques
in which the use of a future system
is concretely described at an early point
in the development process.

SCENARIO-BASED DESIGN

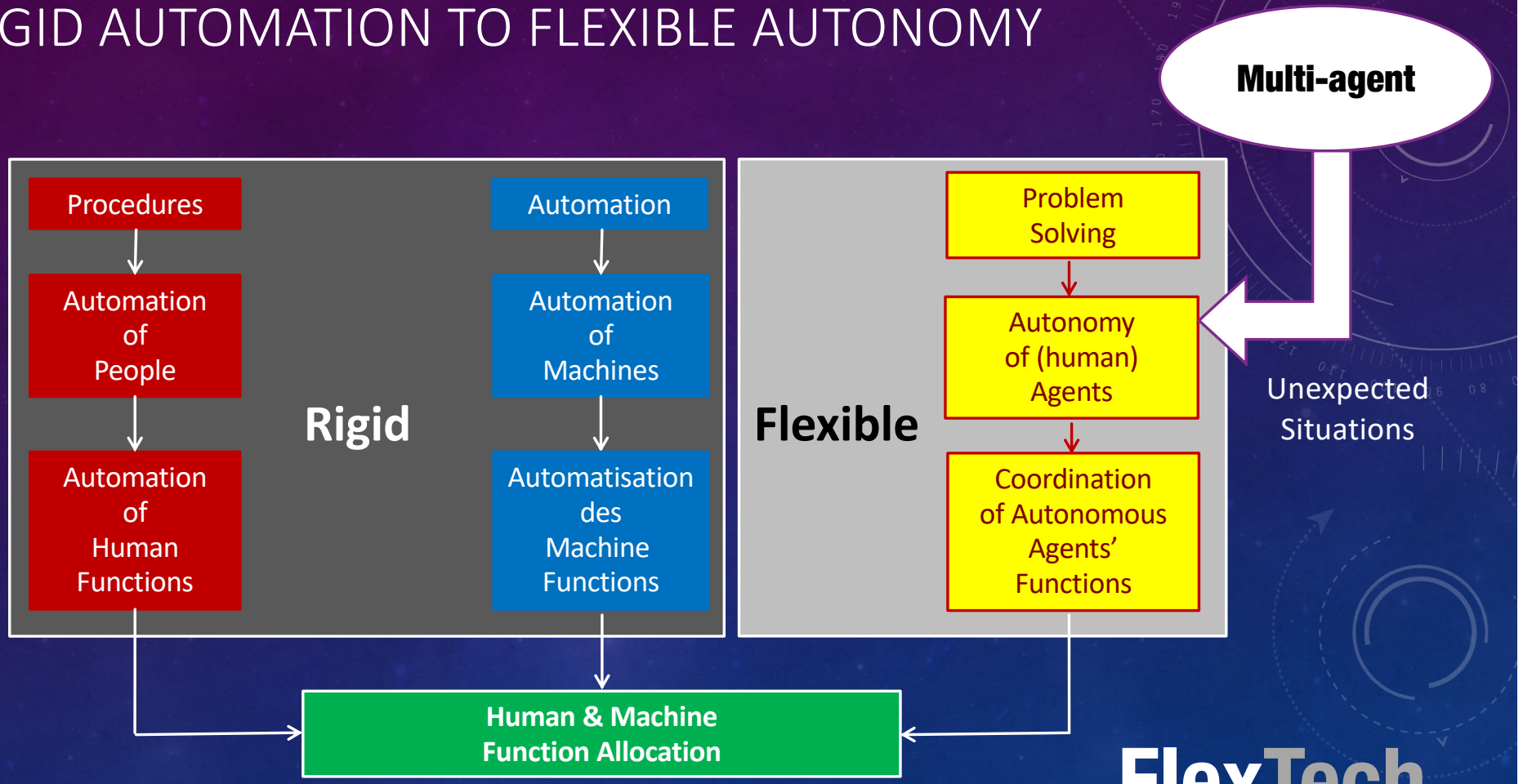
Two examples of SBD projects:

- RVT: virtual air traffic control center
- MOHICAN: onboard virtual assistant HSI

- Storytelling of current practice
- Reveal aspects of the stakeholders and their activities that have implications for design
- Common ground for the project team
- Describe activities in the problem domain
- In SBD, new activities are always grounded in current activities

SCENARIOS ARE STORIES

FROM RIGID AUTOMATION TO FLEXIBLE AUTONOMY



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A STORY ABOUT REMOTE VIRTUAL TOWERS (RVT)

Story → Objectives

- **Cost savings**
  - Tower construction
  - Tower maintenance
- **Pooling of resources**
  - Same center for several airfields with low traffic volume
- **Possibilities regarding deployment**
  - Military external operations
  - Isolated areas (islands)
- **System performance**
  - Provide controllers tools that were not available in traditional towers

Alexandre Disdier's Ph.D. program project

FROM PHYSICAL TO VIRTUAL

- The targeted virtual center should:
  - Provide the same features as traditional tower
  - Not just be a heavy camera-based restitution of the airfield (most prototypes today)
  - Explore alternative interactions concepts (i.e., non-visual only)
  - Reconsider roles of controllers, technicians, pilots, and non-human elements

→ Designing an ATC virtual center
as a complex sociotechnical system, following an HSI approach…

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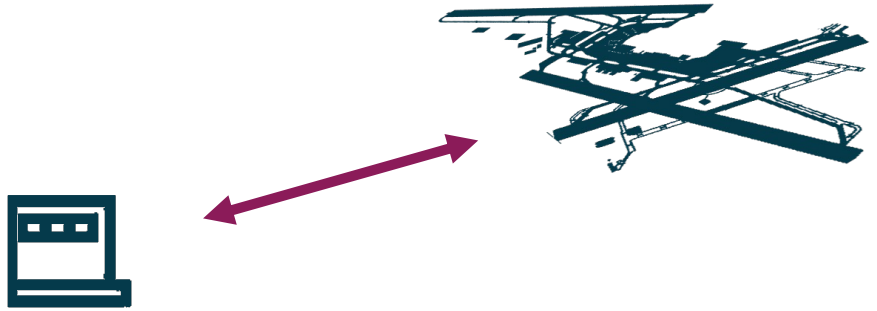
AS-IS → TO BE

What exists

Traditional air traffic control tower

What we want



Remote air traffic control center

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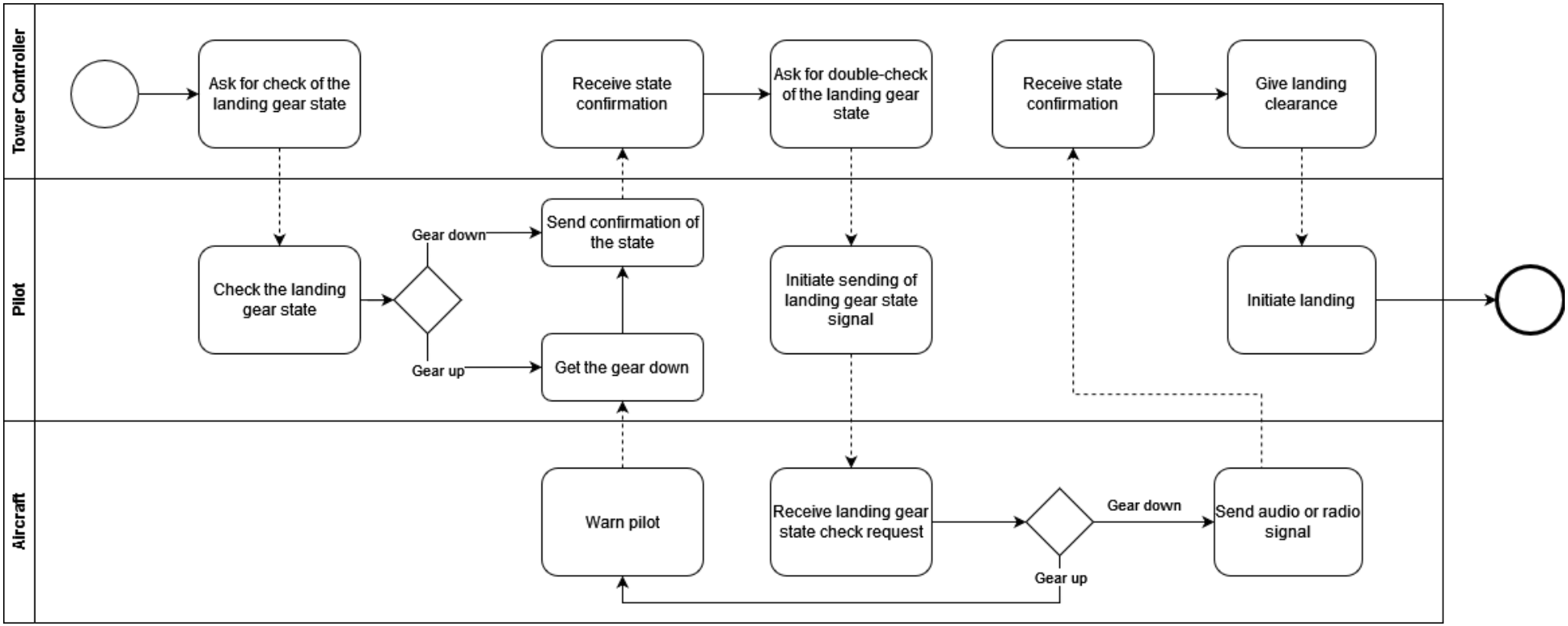
AS-IS FOR THE ATC



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WHAT IS **PRODEC** IN MORE DETAILS?

PROCEDURAL KNOWLEDGE

- Task & activity scenarios
- Contexts of contexts
- Operational experience
- Formalism: iBlocks

DECLARATIVE KNOWLEDGE

- Object & agent configurations
- Systems of systems
- Engineering design expertise
- Formalism: functions and structures

OPERATIONS

PROCEDURAL SCENARIOS

CONTEXT ARCHITECTURE…

… SYSTEM ARCHITECTURE

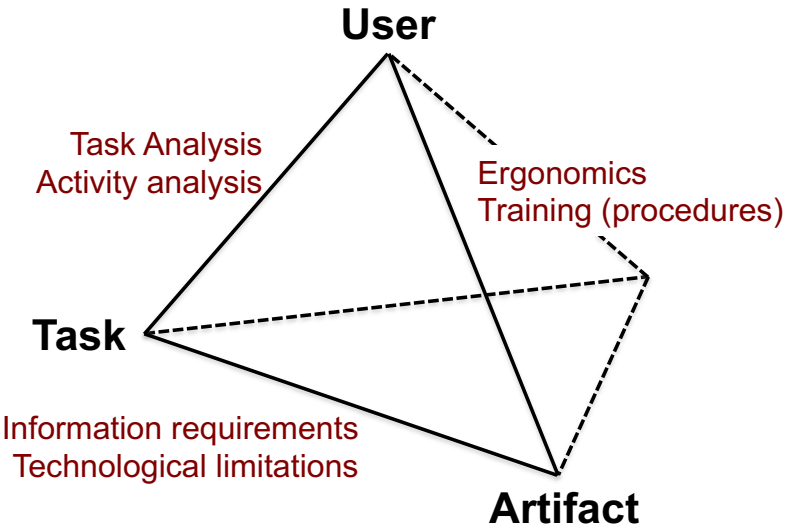
DECLARATIVE CONFIGURATIONS

ENGINEERING DESIGN

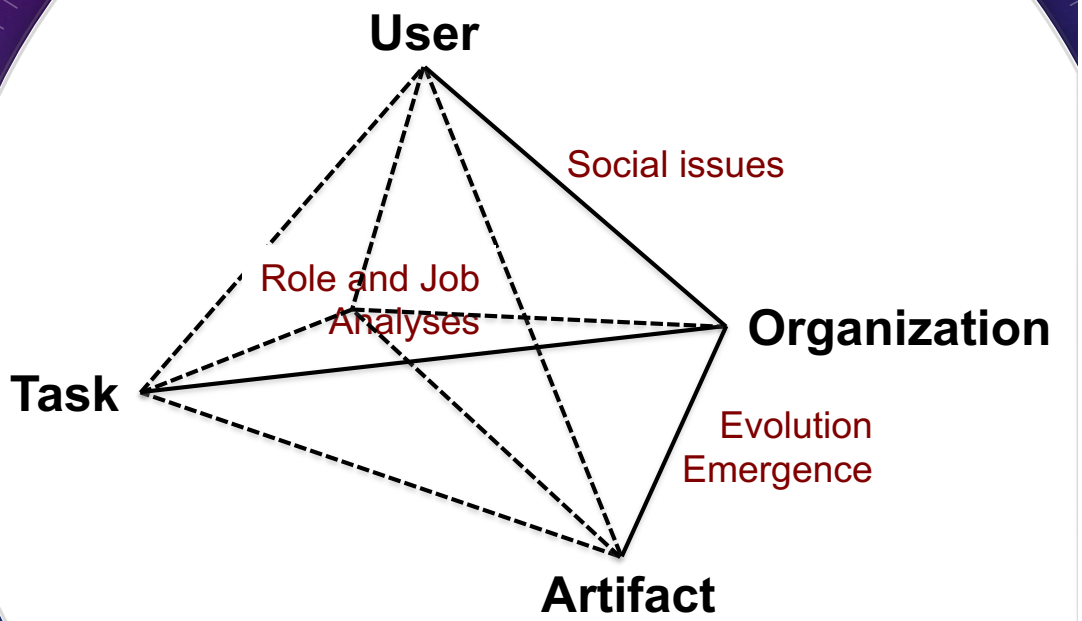
SYSTEMS OF SYSTEMS CONTEXTS OF CONTEXTS

Systems of systems	Contexts of contexts
STRUCTURE & FUNCTION	SITUATIONS
Role	Events
Resources	States
Task	Evolution
Activity	Time & space
Culture	Nominal
Maturity	Off-nominal
Experience & expertise	Emergencies
Integration	Expected & Unexpected

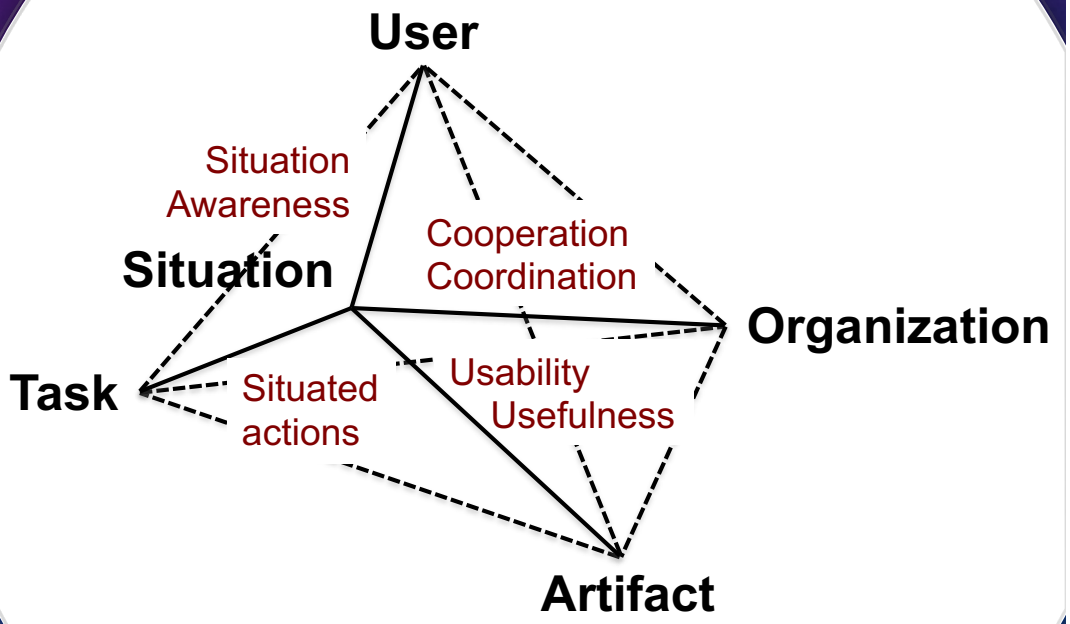
AUT TRIANGLE



AUTO TETRAHEDRON



AUTOS PYRAMID

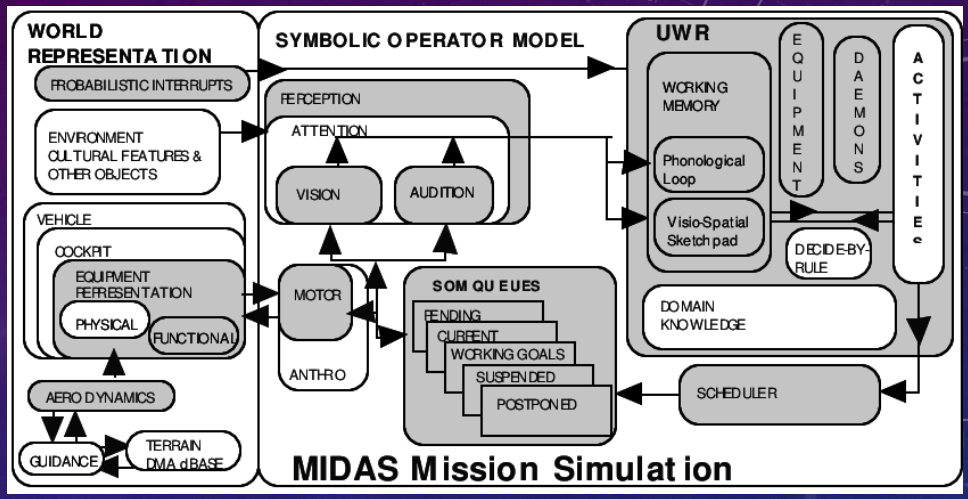


HUMAN MODELING?

- MIDAS (Man-machine Integration Design and Analysis System), MESSAGE…

- Personas are fictional characters, which you create based upon your research to represent the different user types that might use your service, product, site, or brand in a similar way

  → help understand users' needs, experiences, behaviors and goals

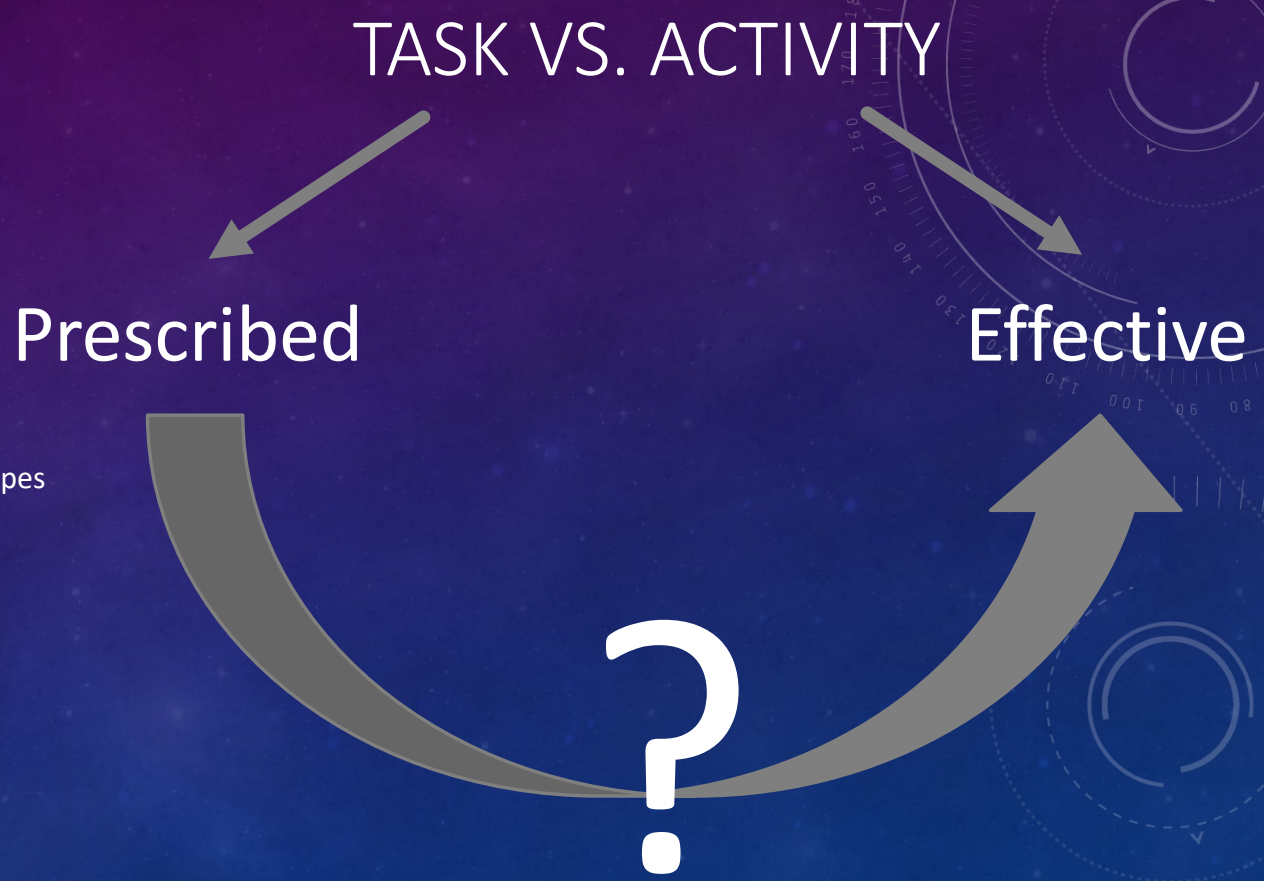


→ Human-in-the-loop simulation (HITLS)

+ Rasmussen's SRK model
+ Endsley's situation awareness model
+ others…

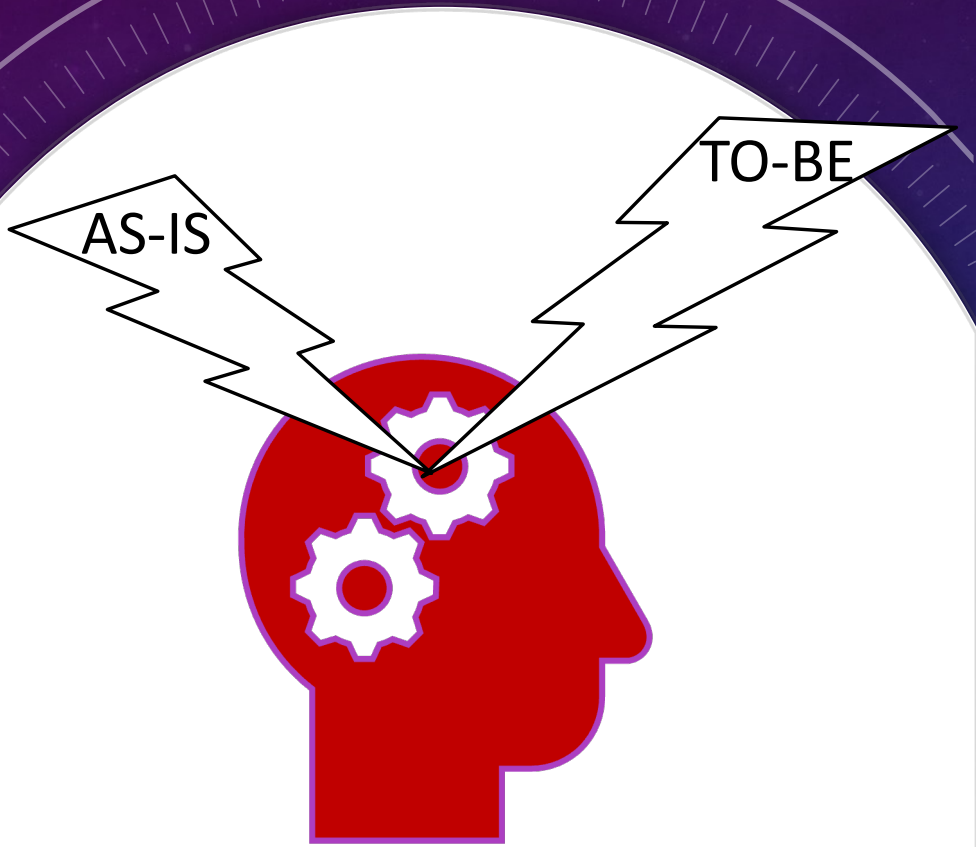
SBD → PRODEC

- Brainstorming
  - Concrete ideas about new functionality
  - New ways of thinking about users' needs
  - How to meet them
- Claims analysis
  - Task analysis
  - Identify tradeoffs as you move forward with prototypes
- Activity observation and analysis
  - Human-in-the-loop simulation
  - Observation protocol
  - Analysis
- Experience feedback process
  - Recommendations synthesis
  - Prototype modification

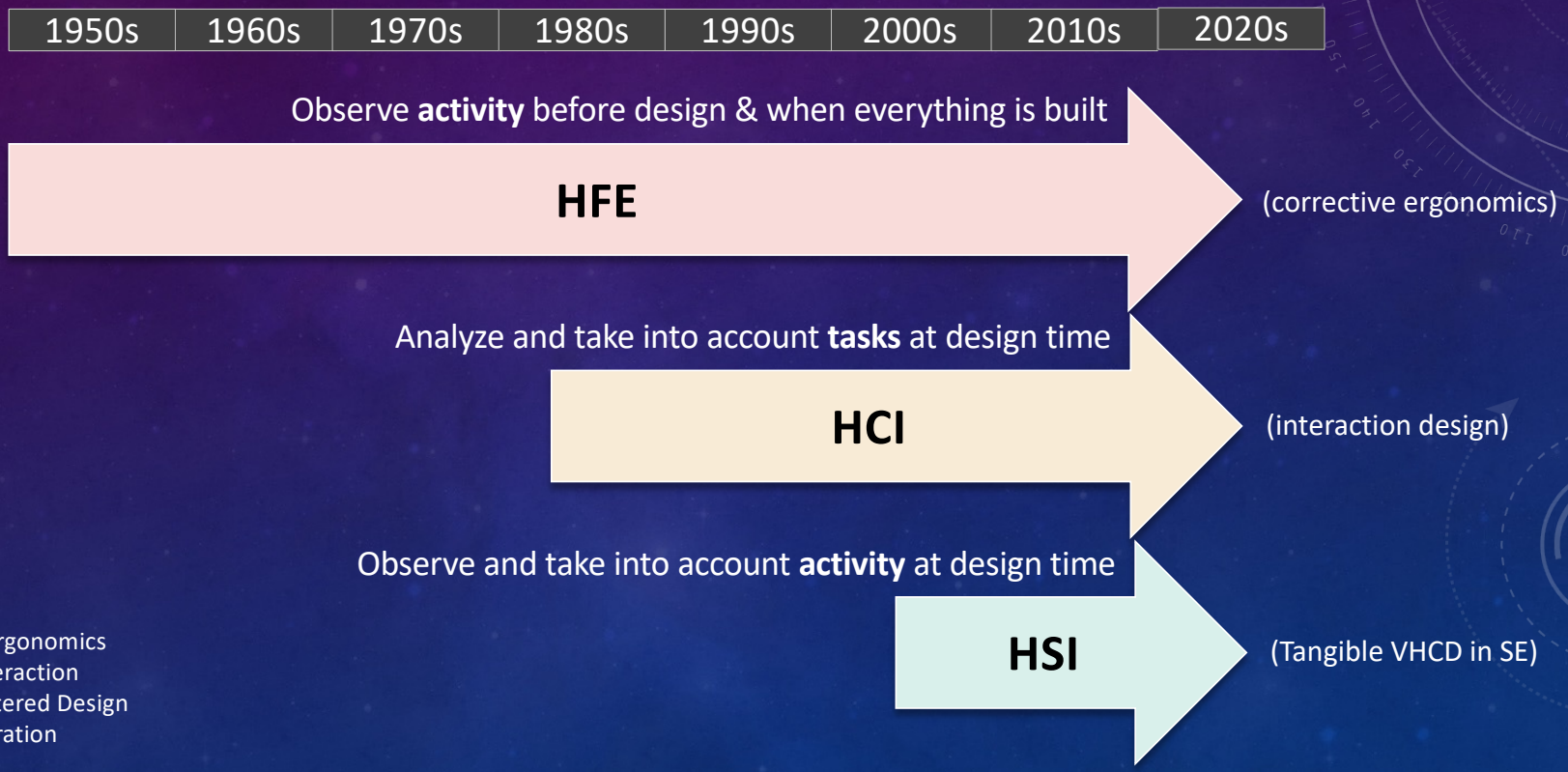


NOT PREDICTION → ANTICIPATION

The difficulty of associating Experience and Creativity.



TASK VS. ACTIVITY

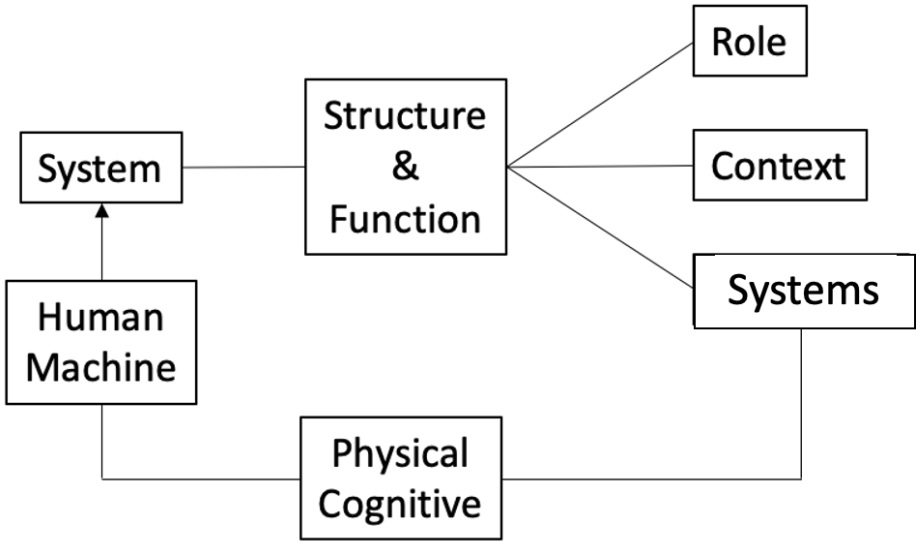


HFE: Human Factors and Ergonomics
HCI: Human Computer Interaction
VHCD: Virtual Human-Centered Design
HSI: Human Systems Integration
SE: Systems Engineering

A SYSTEM REPRESENTING A PROCEDURAL ENTITY

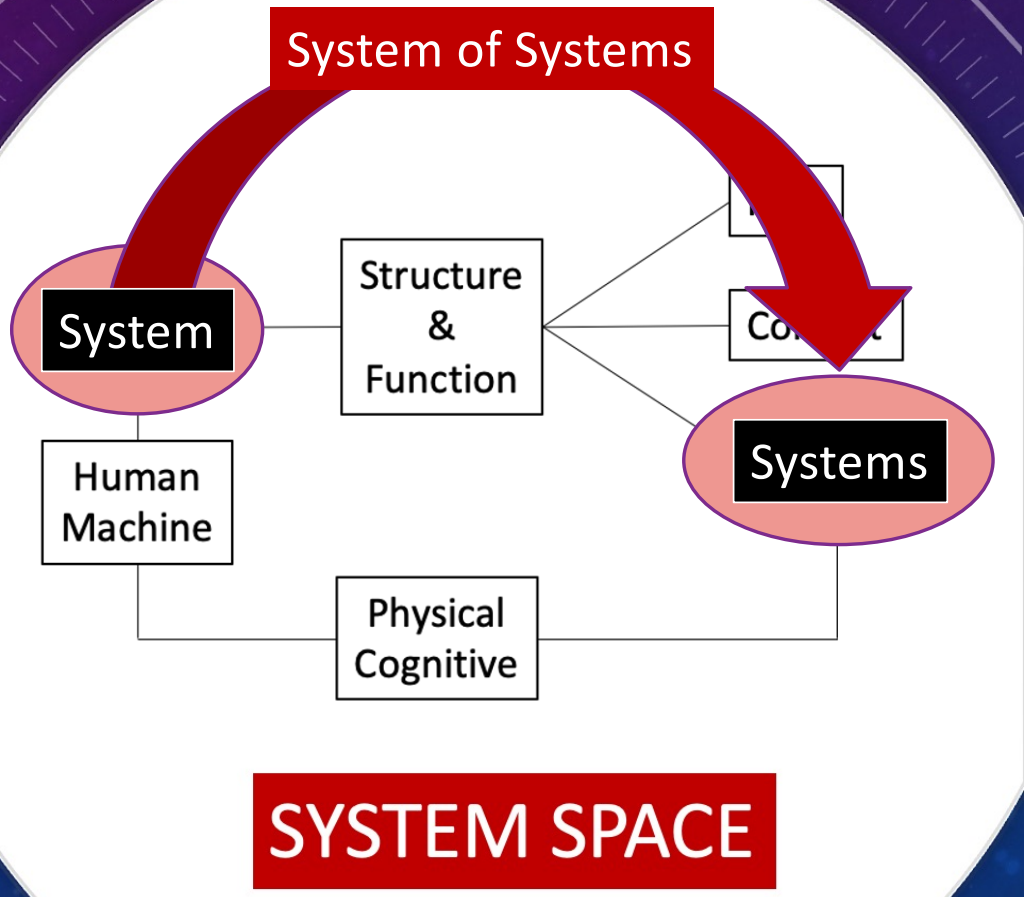
CONTEXT SPACE

A SYSTEM REPRESENTING A DECLARATIVE ENTITY



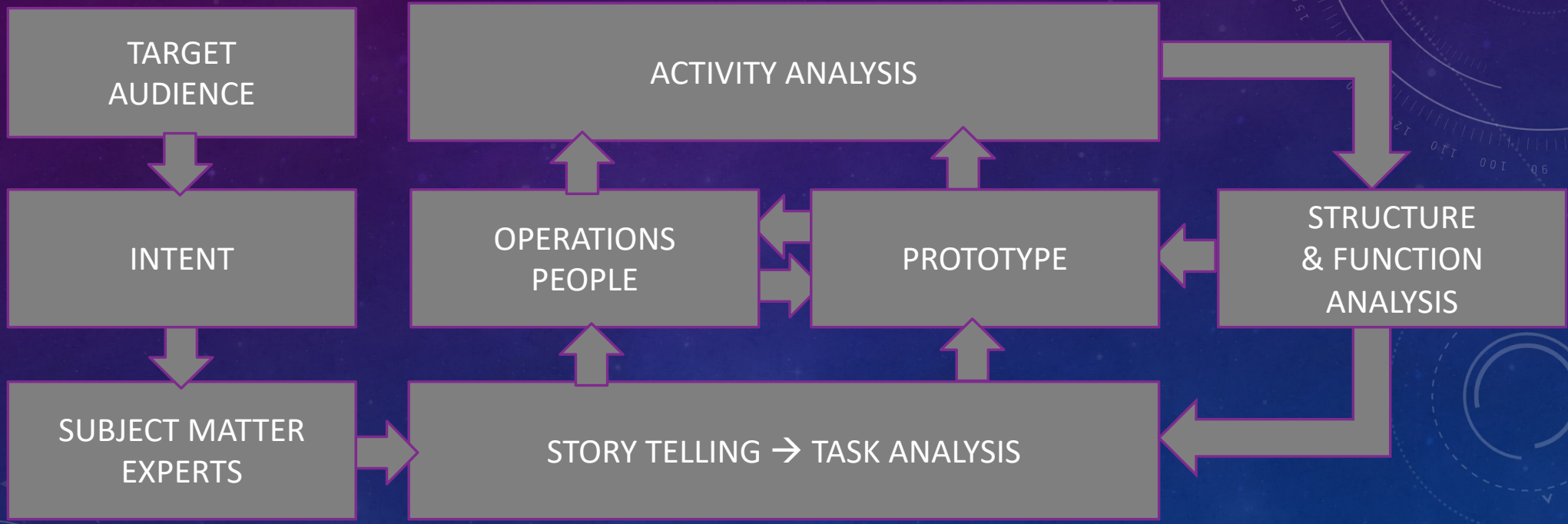
SYSTEM SPACE

A SYSTEM REPRESENTING A DECLARATIVE ENTITY



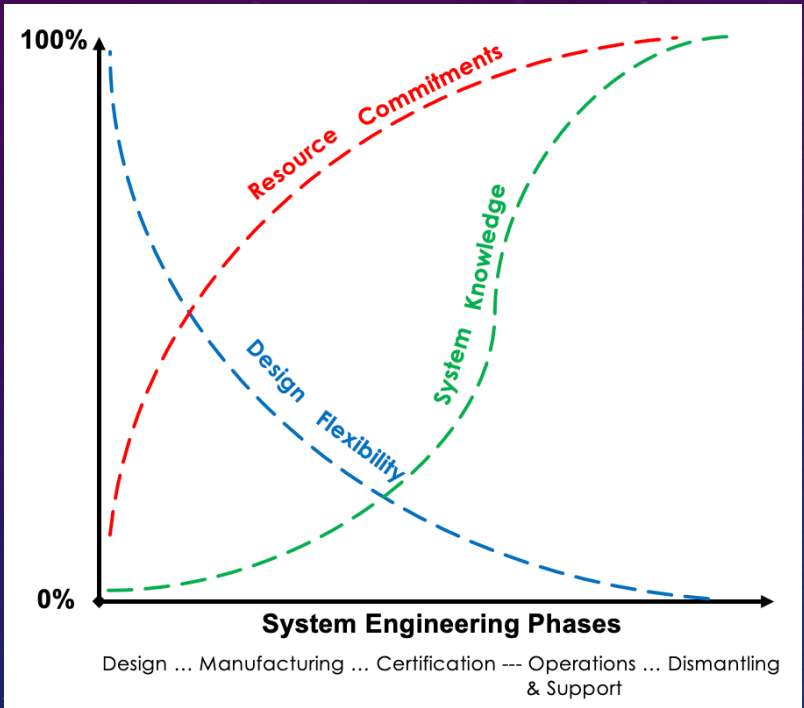
THE T.O.P. MODEL…
… IN HUMAN SYSTEMS INTEGRATION (HSI)

SCENARIO-BASED DESIGN → PRODEC

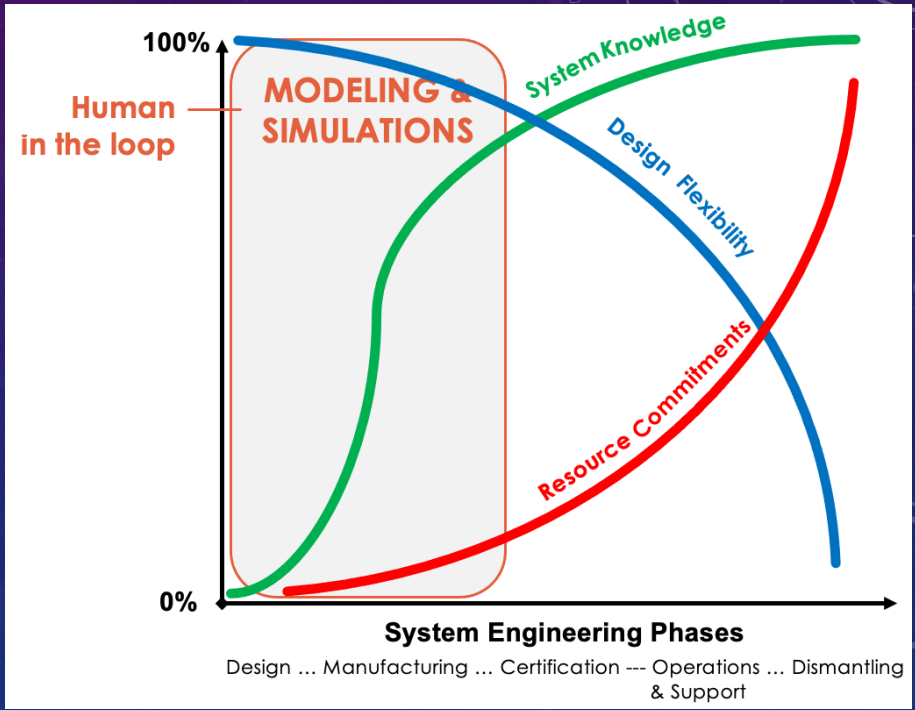


LIFE-CYCLED HUMAN SYSTEMS INTEGRATION

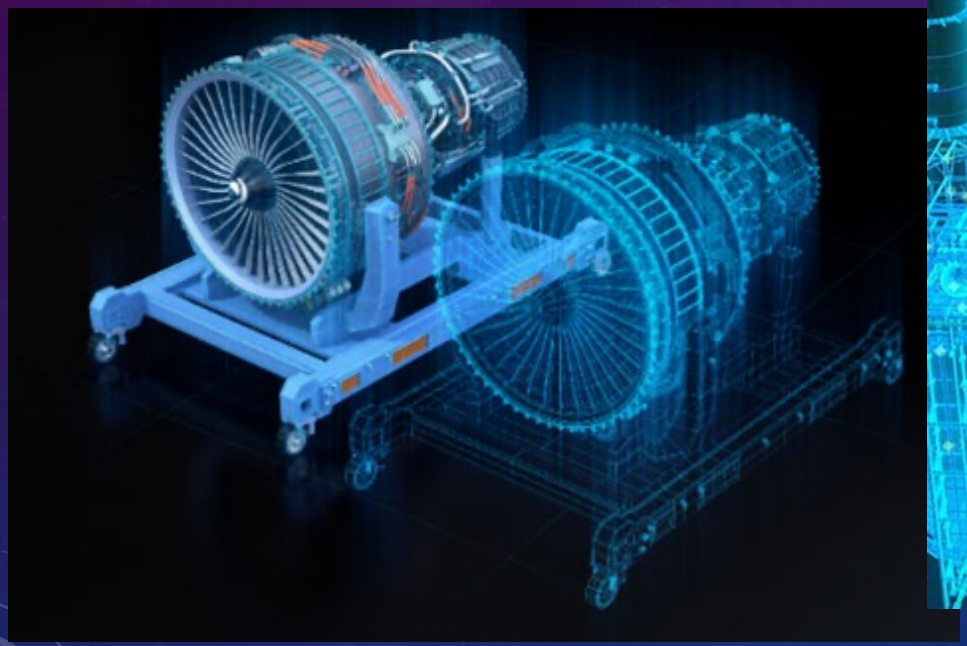
Technology-centered

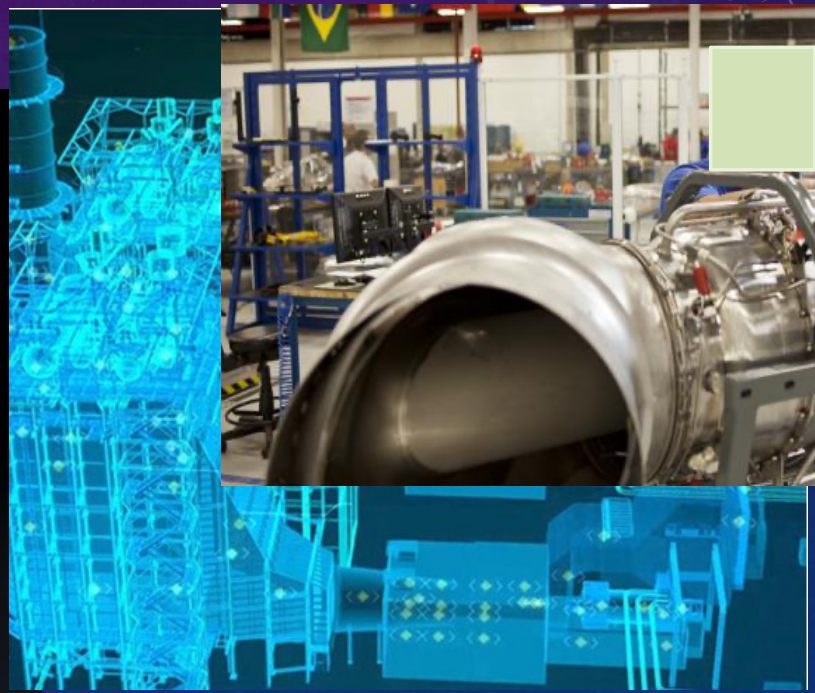


Human-centered



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





DIGITAL TWINS

Expanding HITLS

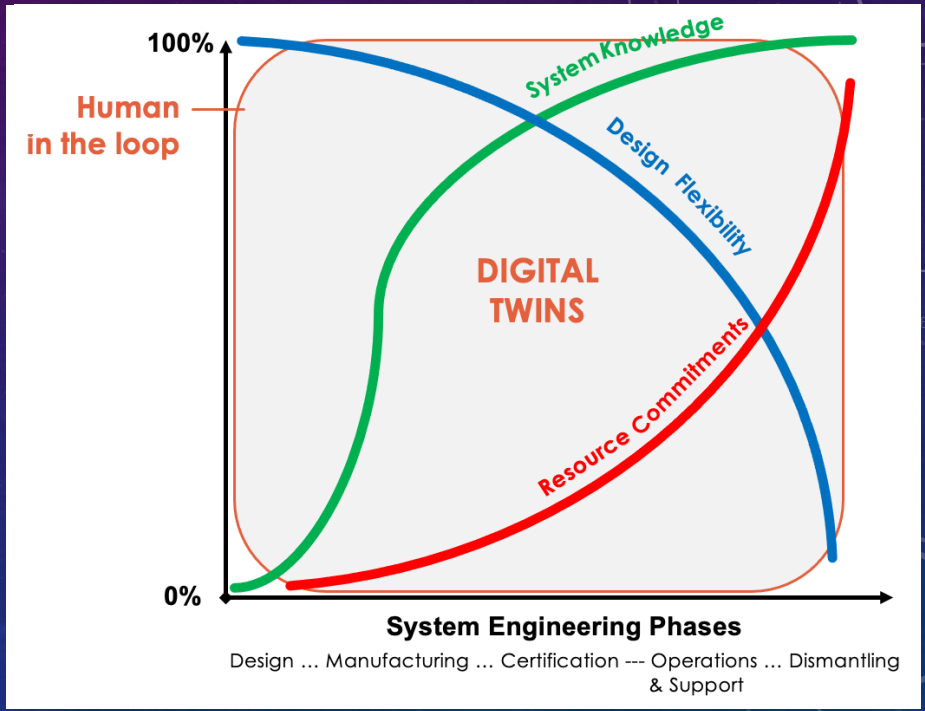
- During the whole life cycle
- “what if?”

Vivid documentation → MBSE

- Integration of experience feedback
- Organizational memory

DTs as virtual assistants → HMT

- Multi-agent collaboration
- Mediators for collaborative work



MBSE: Model-Based Systems Engineering
HMT: Human Machine Teaming
(where the machine is increasingly autonomous)

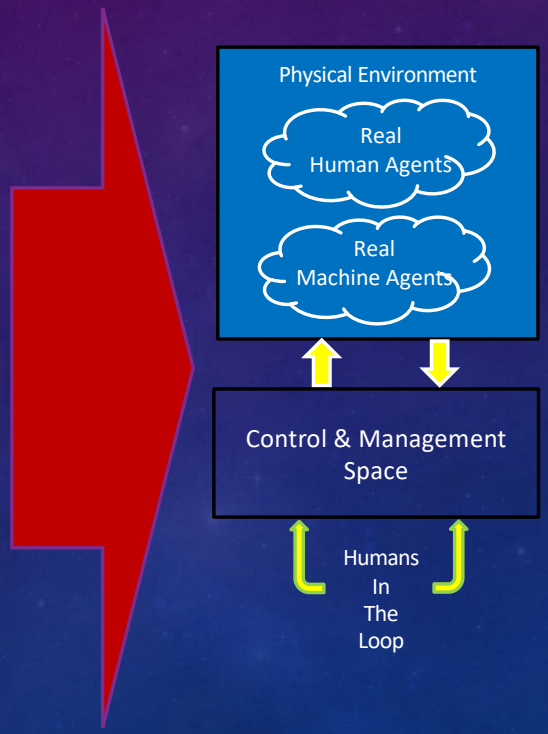
FROM MEANS TO PURPOSE

Engineering

Ergonomics & Automation

Human Factors

Tangible
Human-Centered Engineering

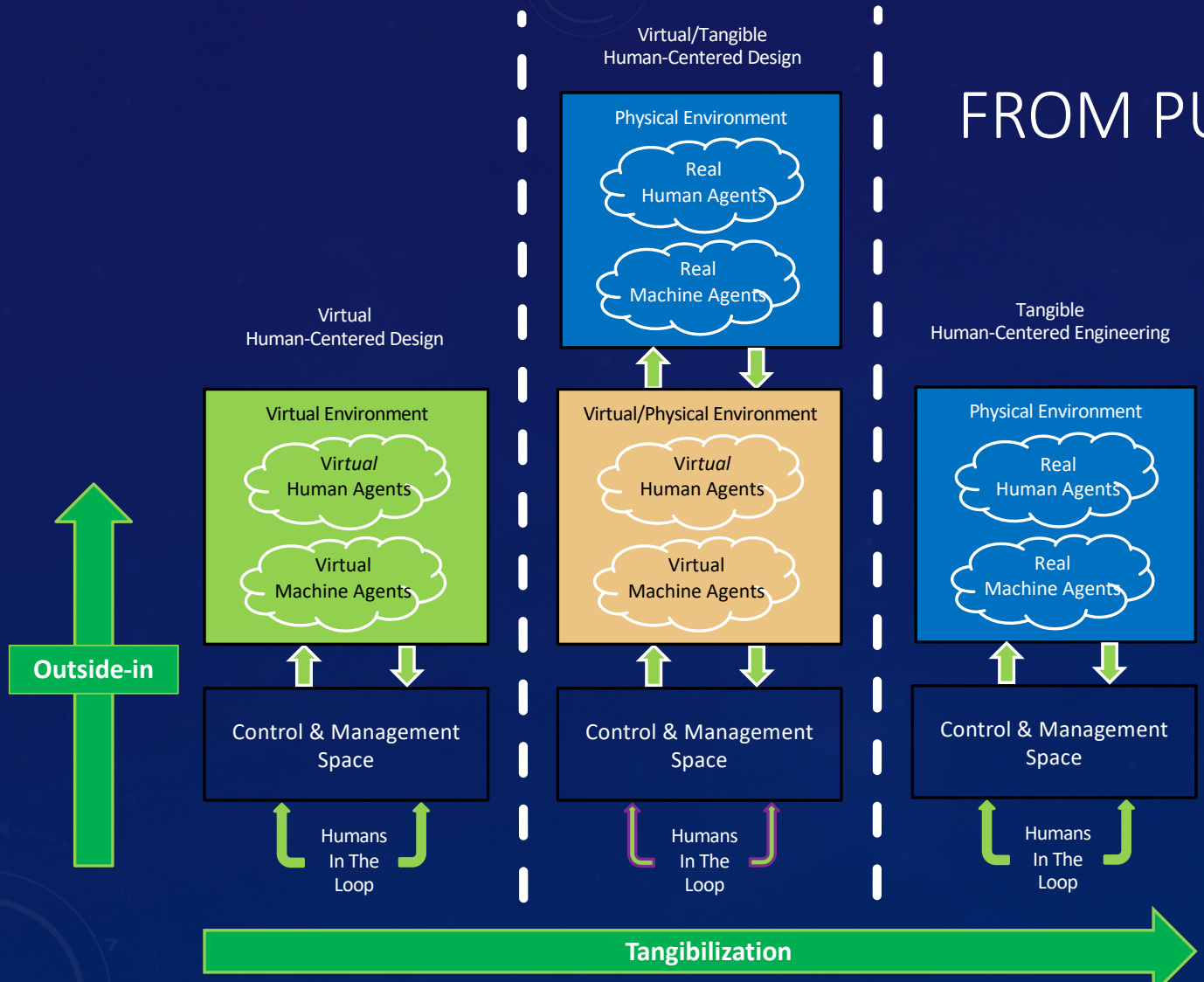


Inside-out

20th century approach

Engineering, Ergonomics, HCI & Automation

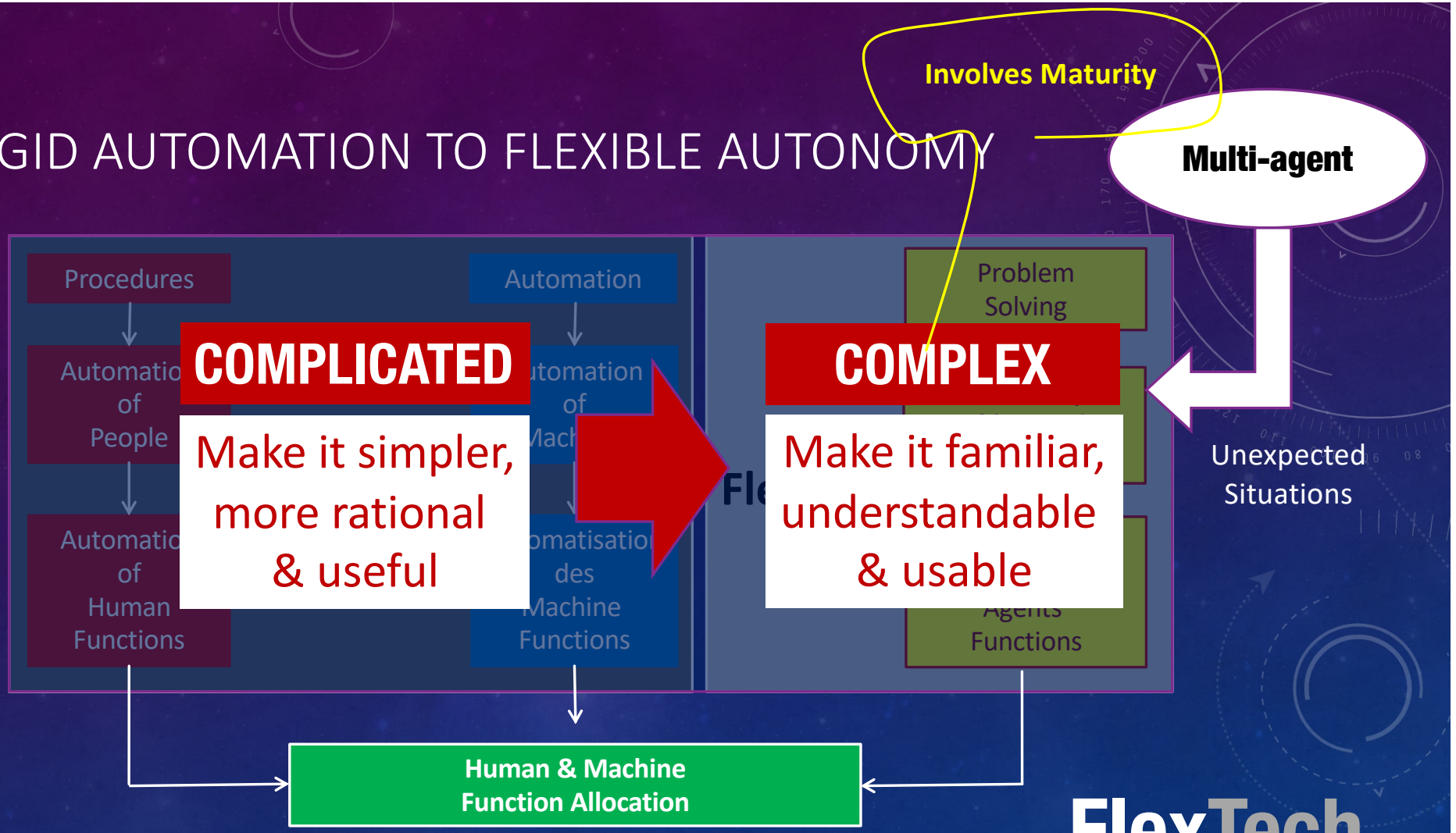
FROM PURPOSE TO MEANS



21ST CENTURY APPROACH

HSI

FROM RIGID AUTOMATION TO FLEXIBLE AUTONOMY



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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

FLEXIBILITY?

COMPLICATED

Make it simpler, more rational & useful

COMPLEX

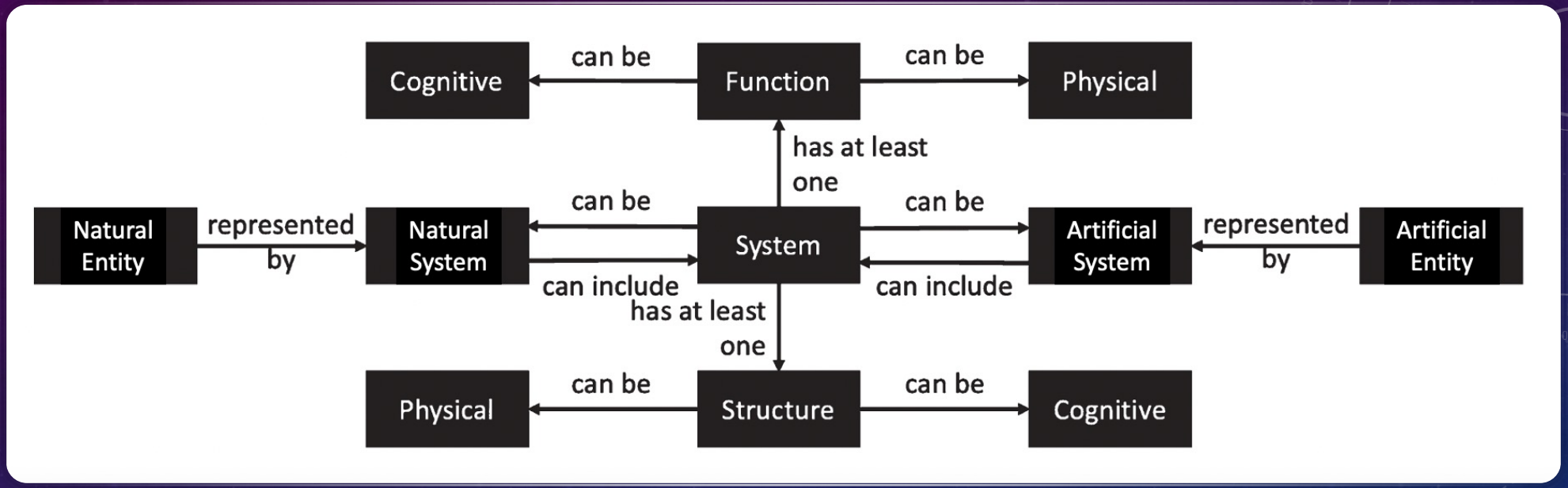
Make it familiar, understandable & usable

RIGID

FLEXIBLE

FOR OPERATIONS & ENGINEERING DESIGN

→ **Need for a systemic representation that covers both humans and machines**



MAKING SYSTEM COMPLEXITY EXPLICIT…

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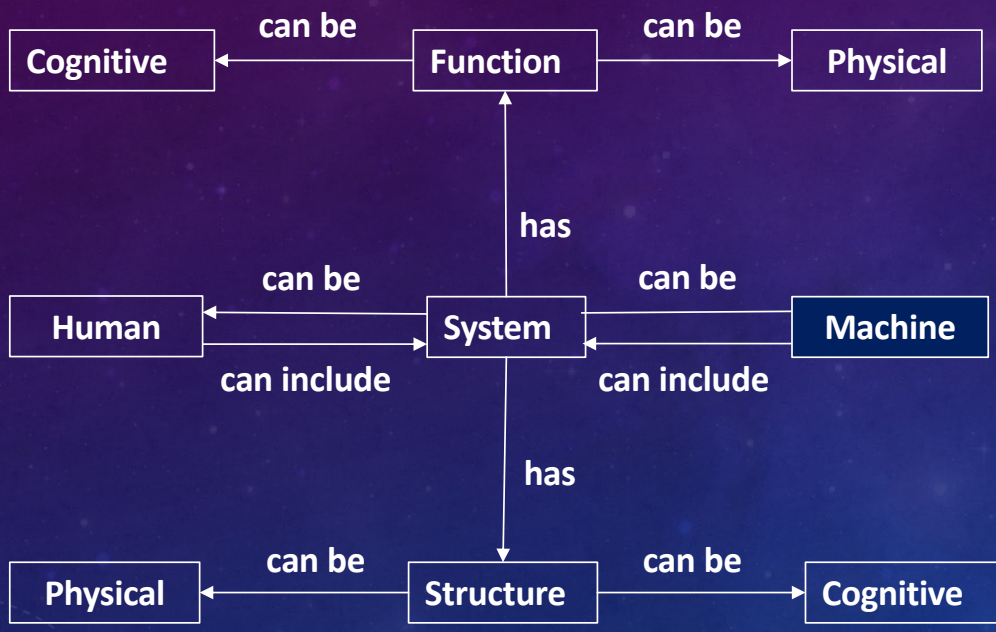
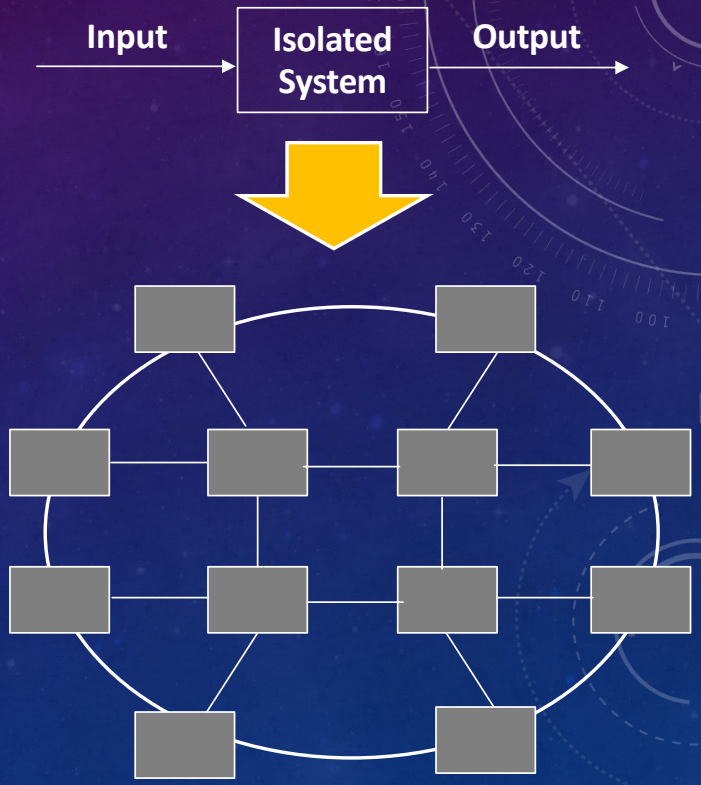


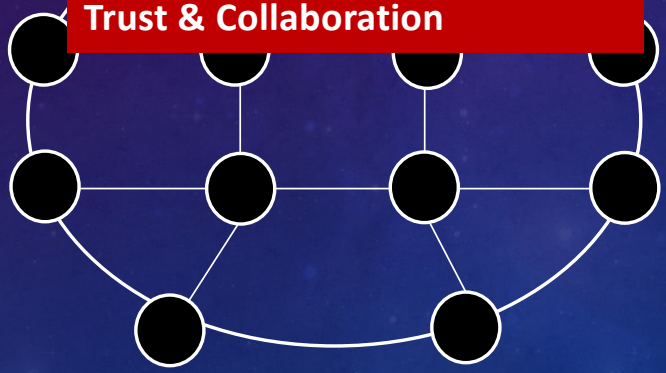
Systems include Humans and Machines…



Interconnected System of Systems

MAKING SYSTEM COMPLEXITY EXPLICIT…

Shared situation awareness
Speed & precision
Resilience
Trust & Collaboration

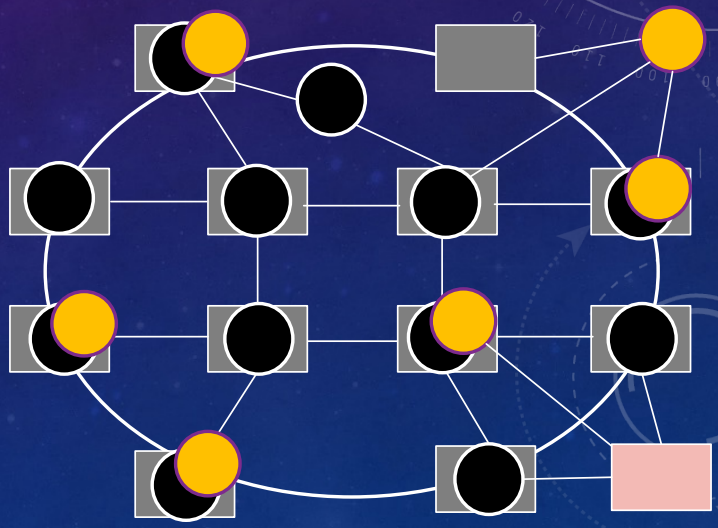


Interconnected Functions of Functions

Emergent Structures

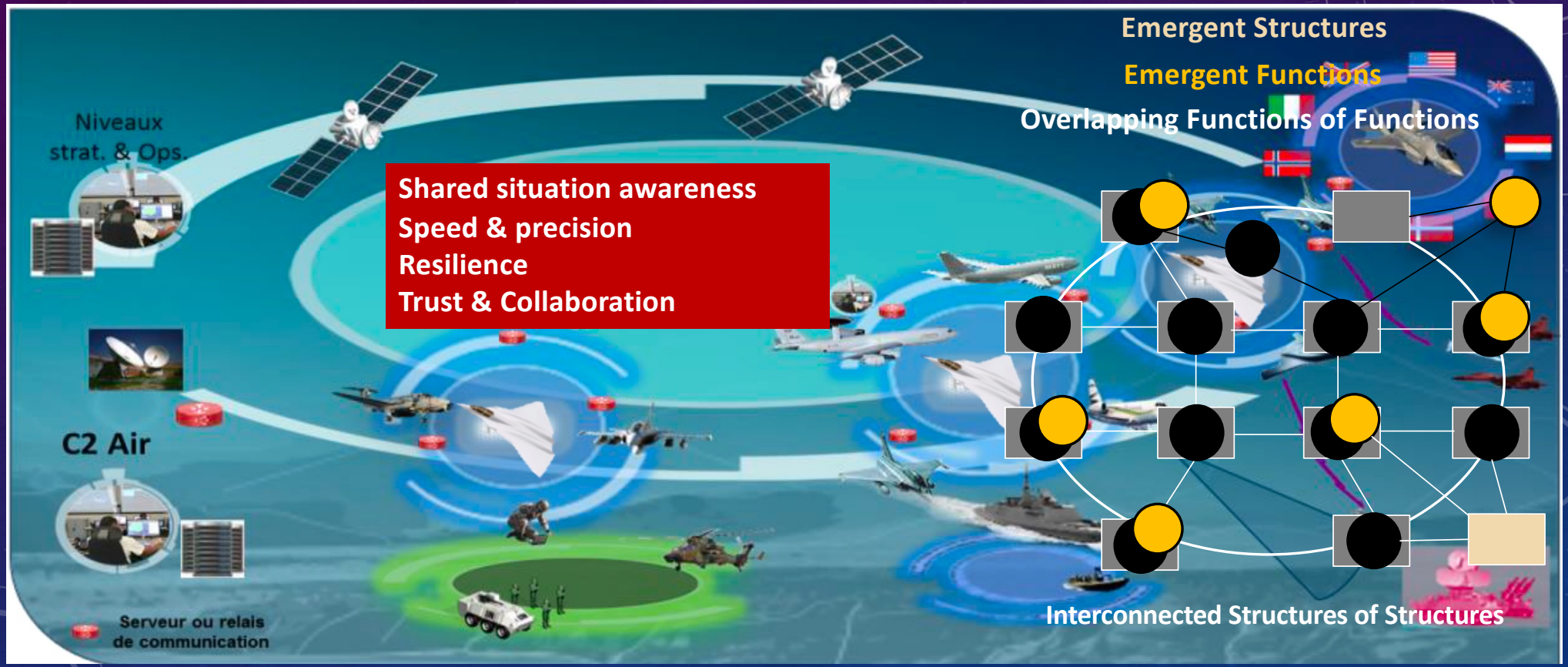
Emergent Functions

Overlapping Functions of Functions



Interconnected Structures of Structures

MAKING SYSTEM COMPLEXITY EXPLICIT…



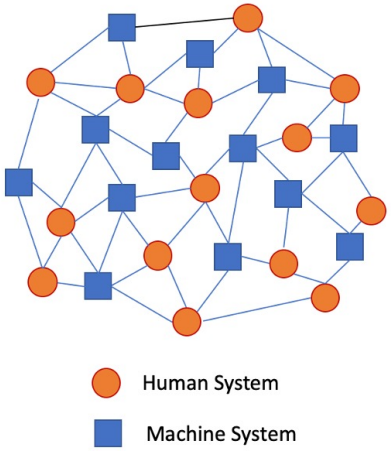


Figure 1. Human & machine systems interacting with each other.

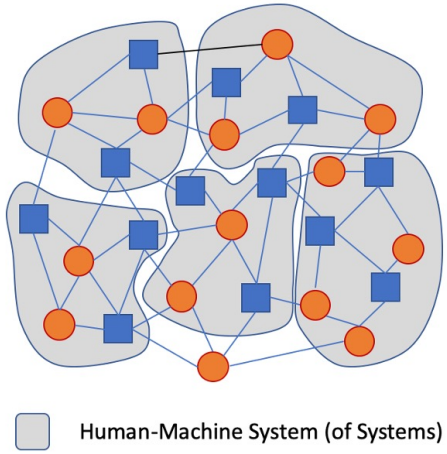
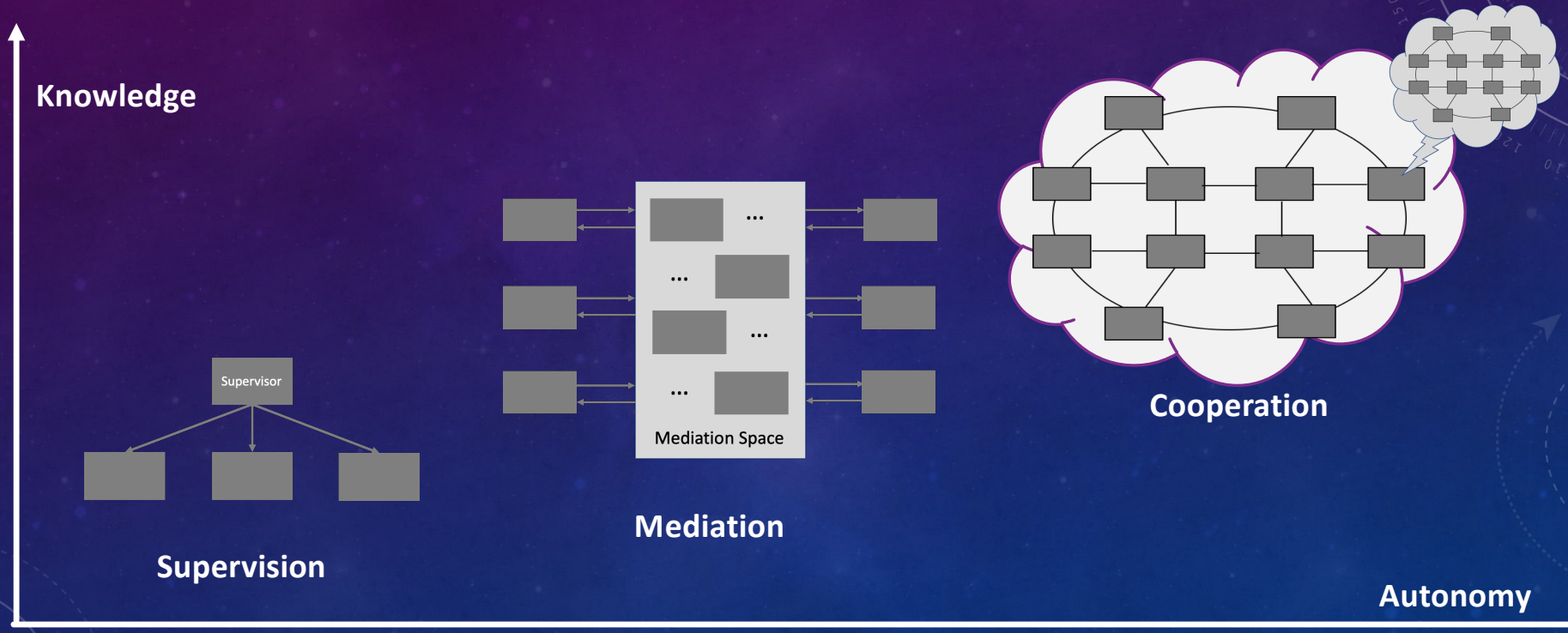


Figure 2. Systems of systems interacting with each other.

- Clarify what is the system of systems
- Analyze separability
- Identify structures and functions
- Make sense of function allocation

MAKING SYSTEM COMPLEXITY EXPLICIT…

SYSTEMIC INTERACTION MODELS…
… AND AUTHORITY SHARING



UNDERSTANDING SYSTEM EMERGENCE

(Boy, 2022)

- **Emergent properties come from *activity***

  Human activity observed once the system is fully integrated

- **Problem: integration done at the end of development**

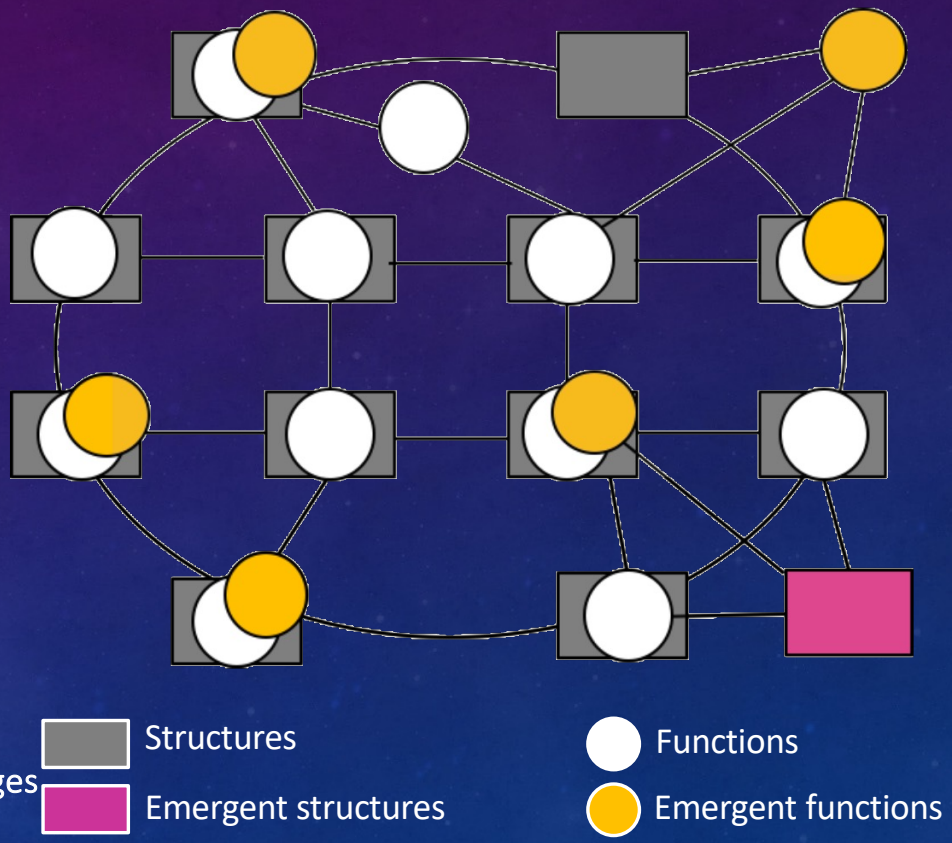
  So activity cannot be observed at design time

  Hence emergent properties cannot be detected early!

- **New solution: human-in-the-loop simulation**

  Enables virtual human-centered design (HCD)

  Support observation of human activity during early design stages



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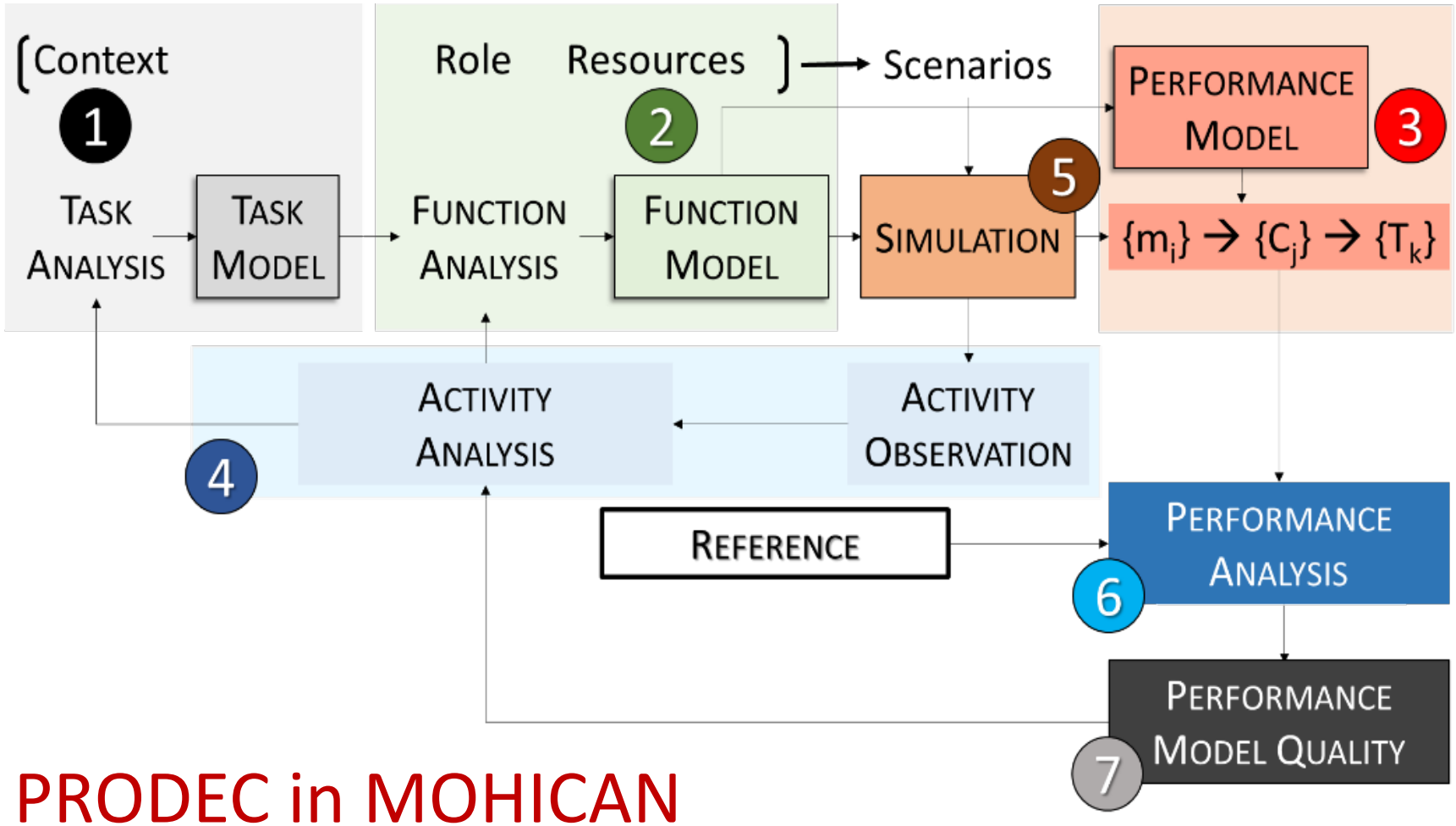
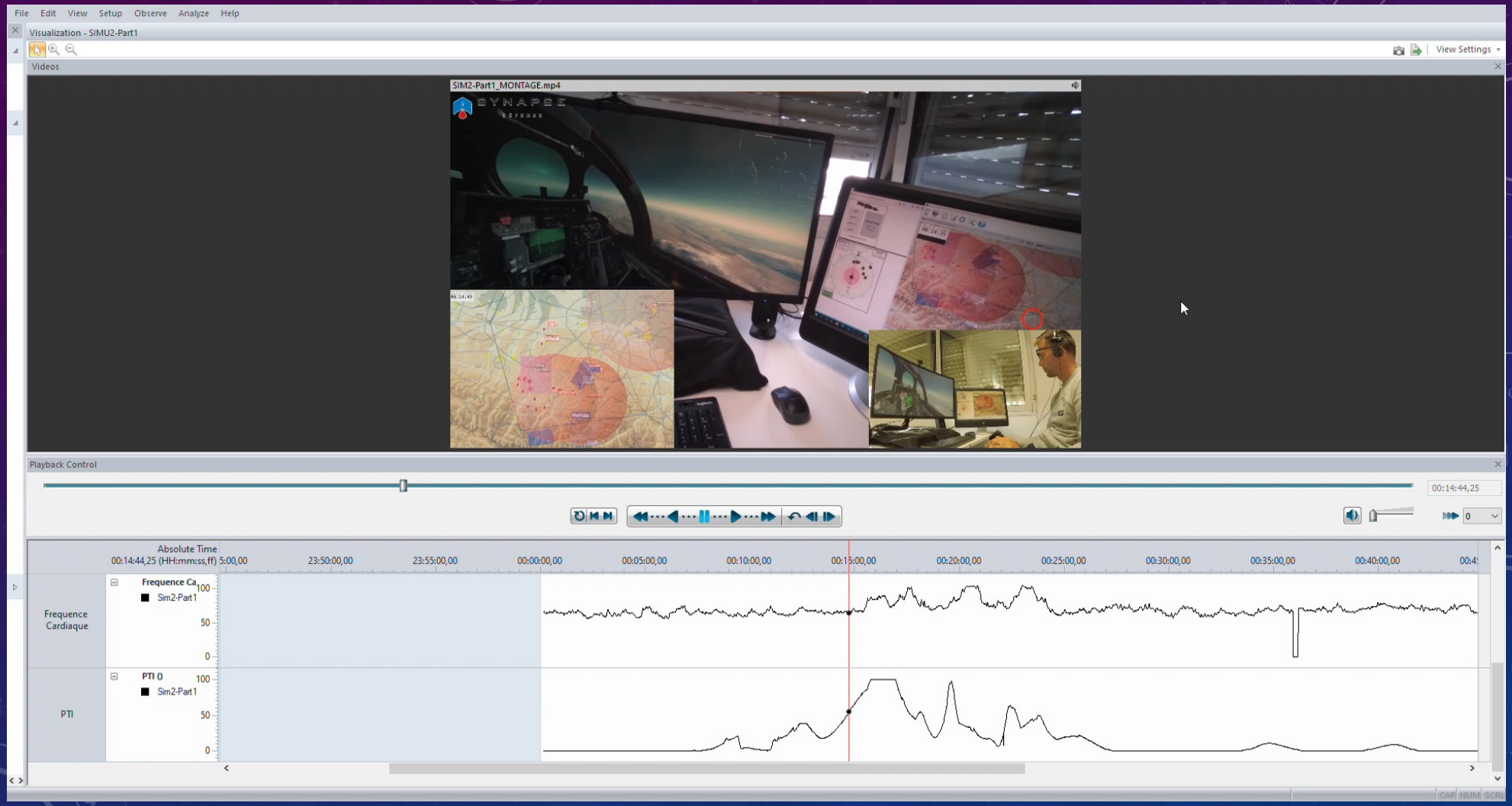


PRODEC in MOHICAN

ILLUSTRATION OF MOHICAN EXPERIMENTAL SET-UP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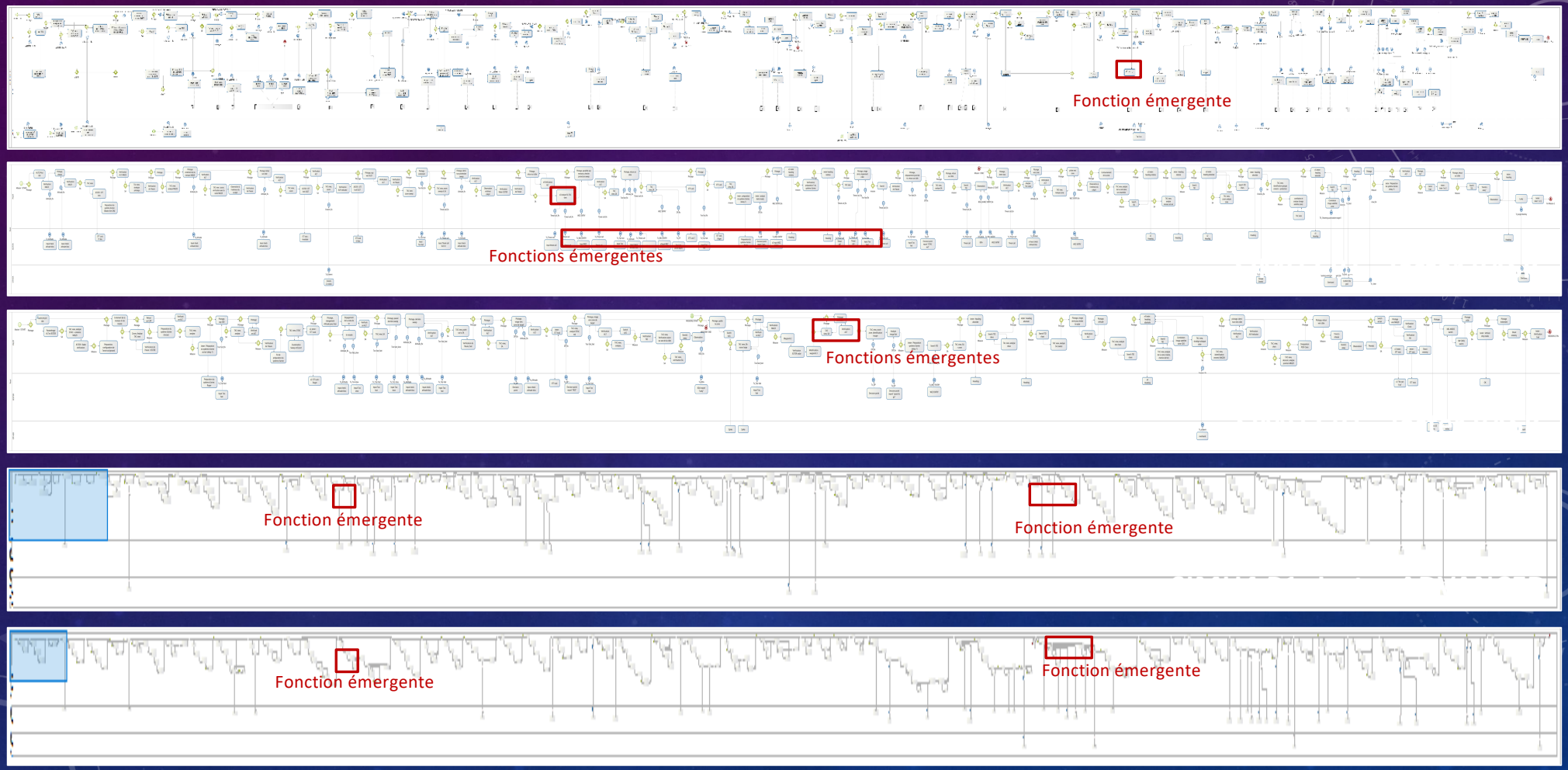
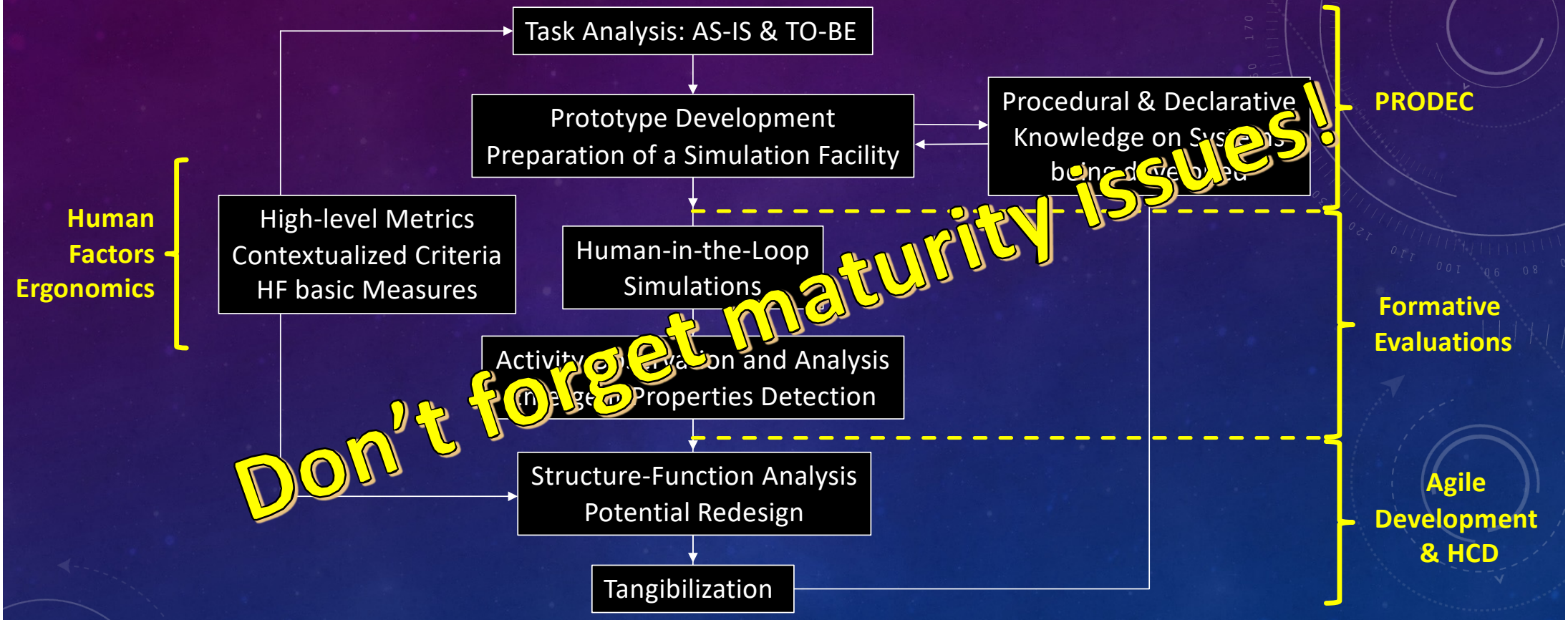
TASK & ACTIVITY ANALYSIS: BPMN



SCENARIO-BASED DESIGN PROCEDURE



Systemic ontology development enables optimal definition of HSI metrics (e.g., trust, collaboration & operational performance)

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THANK YOU

I AM OPEN TO QUESTIONS…