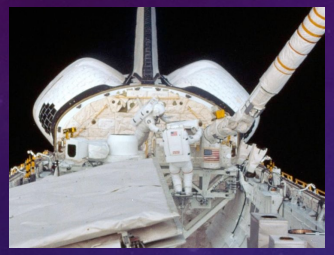
FLEXTECH CHAIR

A HUMAN SYSTEMS INTEGRATION APPROACH

PROFESSOR GUY ANDRÉ BOY

MY WORLD FOR OVER 40 YEARS...

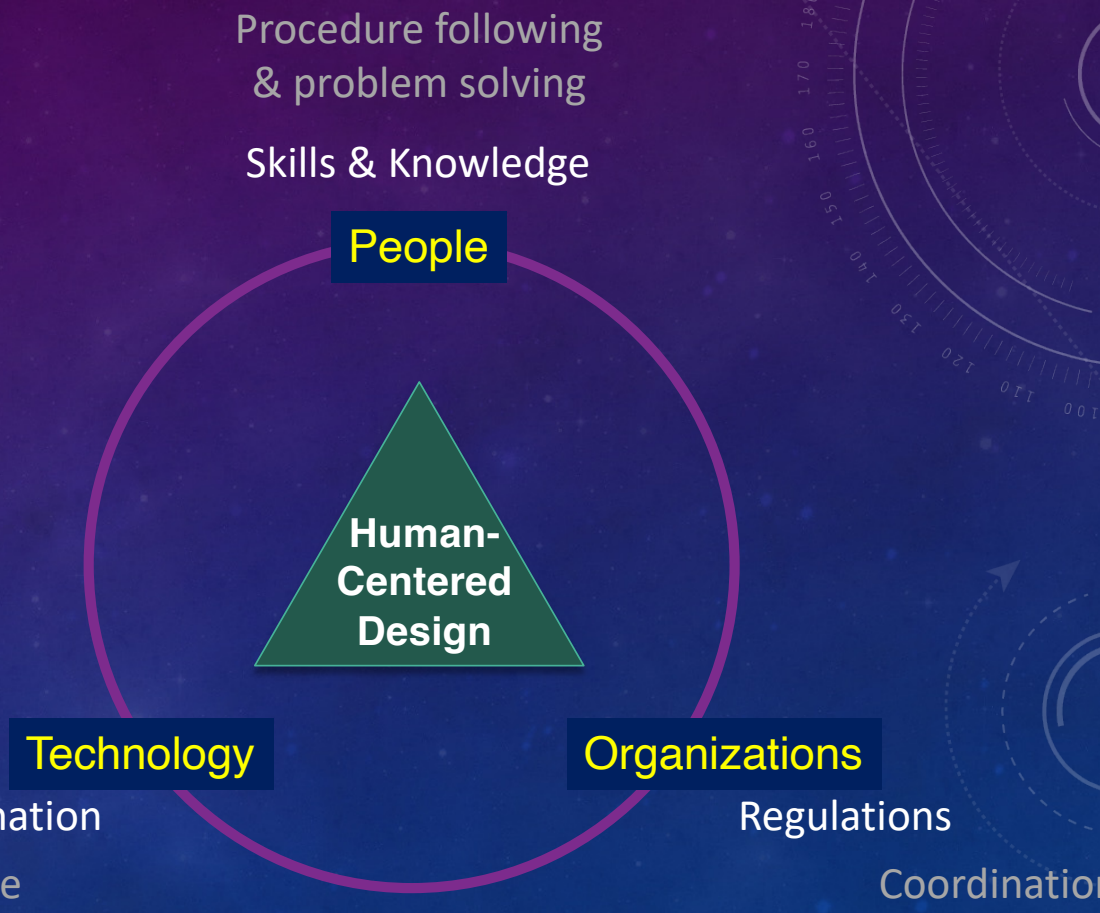


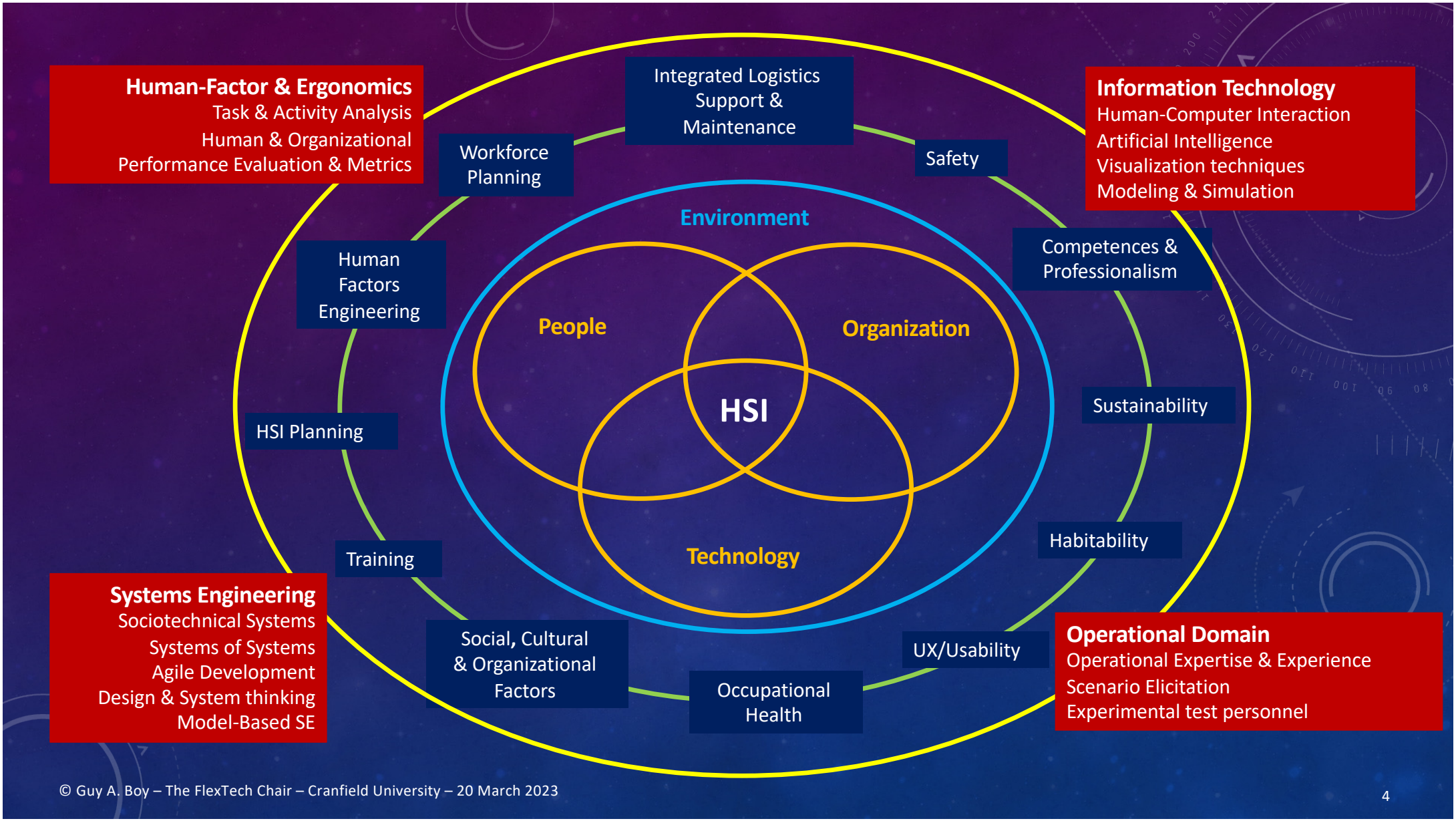
... in engineering design
and in operations

From correction to interaction to integration

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

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





LET'S INTRODUCE THE FLEXTECH CHAIR…

FlexTech
CentraleSupélec-ESTIA Chair

FlexTech

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HUMAN SYSTEMS INTEGRATION (HSI) IN INCREASINGLY AUTONOMOUS SYSTEMS

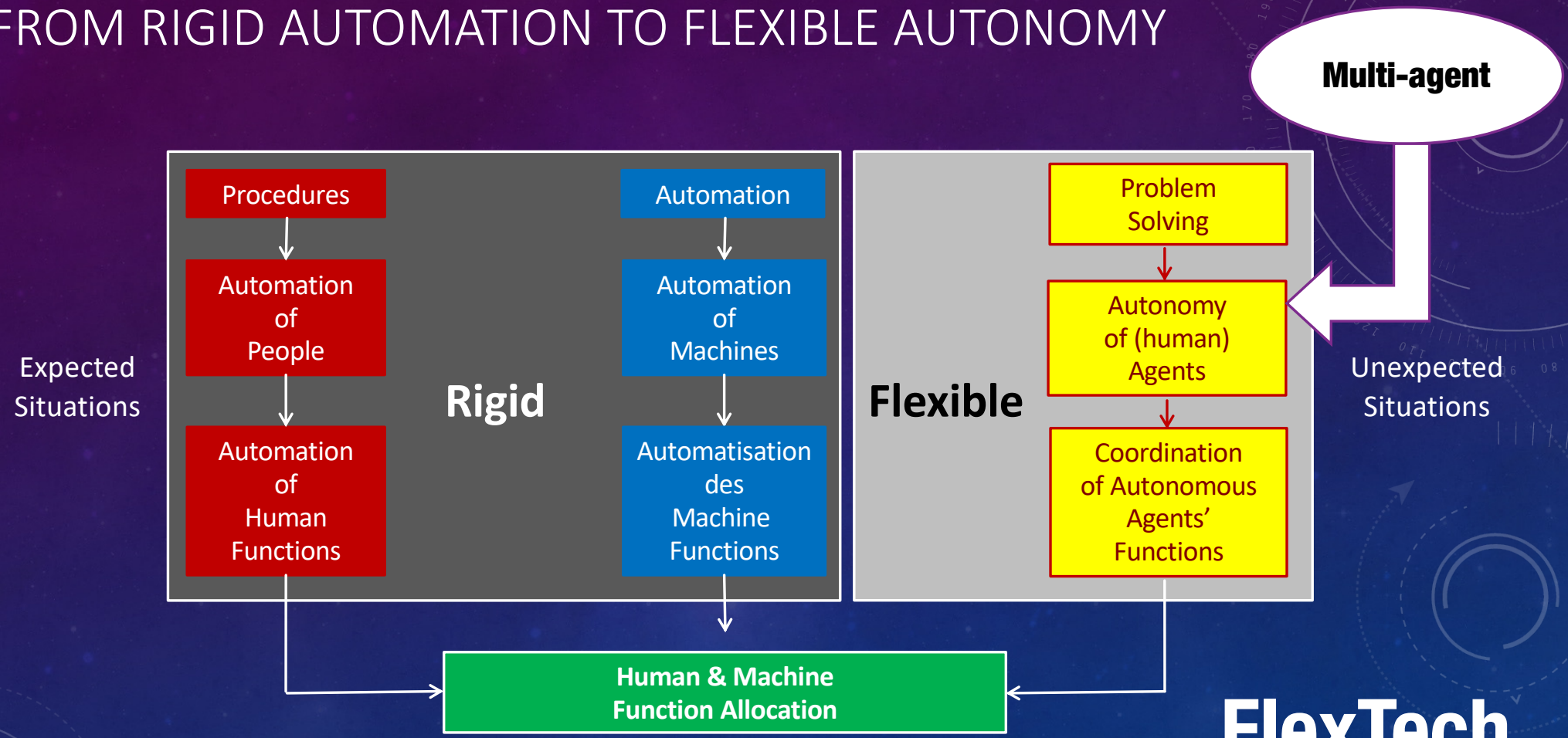
Digital Engineering

Role of people and organizations in life-critical complex systems

Development of new approaches, methods and tools

Applications in various industrial sectors, e.g., aerospace, defense, oil-&-gas, health, automotive, nuclear, and others

FROM RIGID AUTOMATION TO FLEXIBLE AUTONOMY



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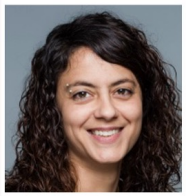
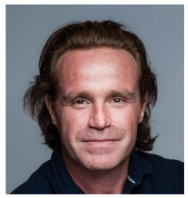
FLEXTECH ACTORS …

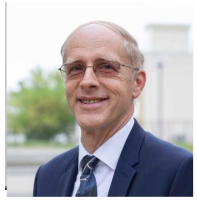

Audrey Abi Akle

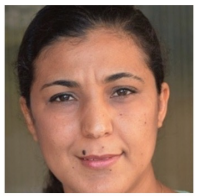

Guy André Boy


Élise Durnerin


Marija Jankovic


Jérémy Legardeur


Rob Vingerhoeds


Hind Bril El Haouzi


Anne Barros

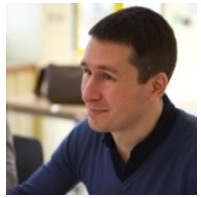

Dimitri Masson


Christophe Merlo


Chloé Morel


Philippe Palanque


Eric Villeneuve


Stéphane Vales


Cynthia Lamothe

+ ~100 students
3A & Master/year

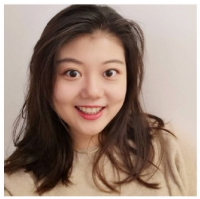

Bernard Yannou


Mohanad Bikai


Stélian Camara


Quentin Lorente


Alexandre Disdier


Yang Sun

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ACADEMIC PARTNERS

1. FlexTech
   - CentraleSupélec
   - ESTIA
2. External Partners
   - ENSC
   - ISAE-SUPAERO
   - ESCP Business School
   - Autres…

HSI Course taught at Master & doctoral levels

Created in September 2019

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INSTITUTIONAL & INDUSTRIAL PARTNERS

1. French Air & Space Forces
2. CS Group
3. Thales
4. Ingenuity
6. Clients via ESTIA (DGA, TotalEnergies, SAFRAN)

Cross-Fertilization of various HSI projects

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A MAJOR RESEARCH TOPIC EMERGED …

PRODEC method emerged from various applicative research projects

PRODEC is currently developed:

- to capture and analyze existing operations (AS-IS)
- to overcome major obstacles, mainly information exchanges (TO-BE)
- to dig technological, organizational and human gaps towards a successful digital transformation
- to allow the analysis, design, and evaluation of data exchanges, and support the validation of all possible transformation

Towards a modeling platform that supports considering people and organizations all along the life cycle of a system

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INDUSTRIAL USE CASES USING PRODEC

MOHICAN: trust & collaboration with a virtual assistant (DGA, Thales, Dassault Aviation)

Virtual air traffic control center (CS Group & French Air & Space Forces)

Increasingly autonomous trains (SNCF)

Future Combat Air System (Thales)

Off-shore robotics remote management (TotalEnergies)

Remote maintenance of helicopter engines (Safran)

INNOMED: a new health system with general practitioner at the center

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LET'S TAKE AN EXAMPLE…

THE MOHICAN PROJECT

VIRTUAL ASSISTANT IN AIR COMBAT AIRCRAFT

A RESEARCH EFFORT SPONSORED BY DGA,

AND SUPERVISED BY THALES AND DASSAULT AVIATION

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MONITORING HUMAN-MACHINE PERFORMANCE BY ANALYZING TRUST AND COOPERATION

Objectives

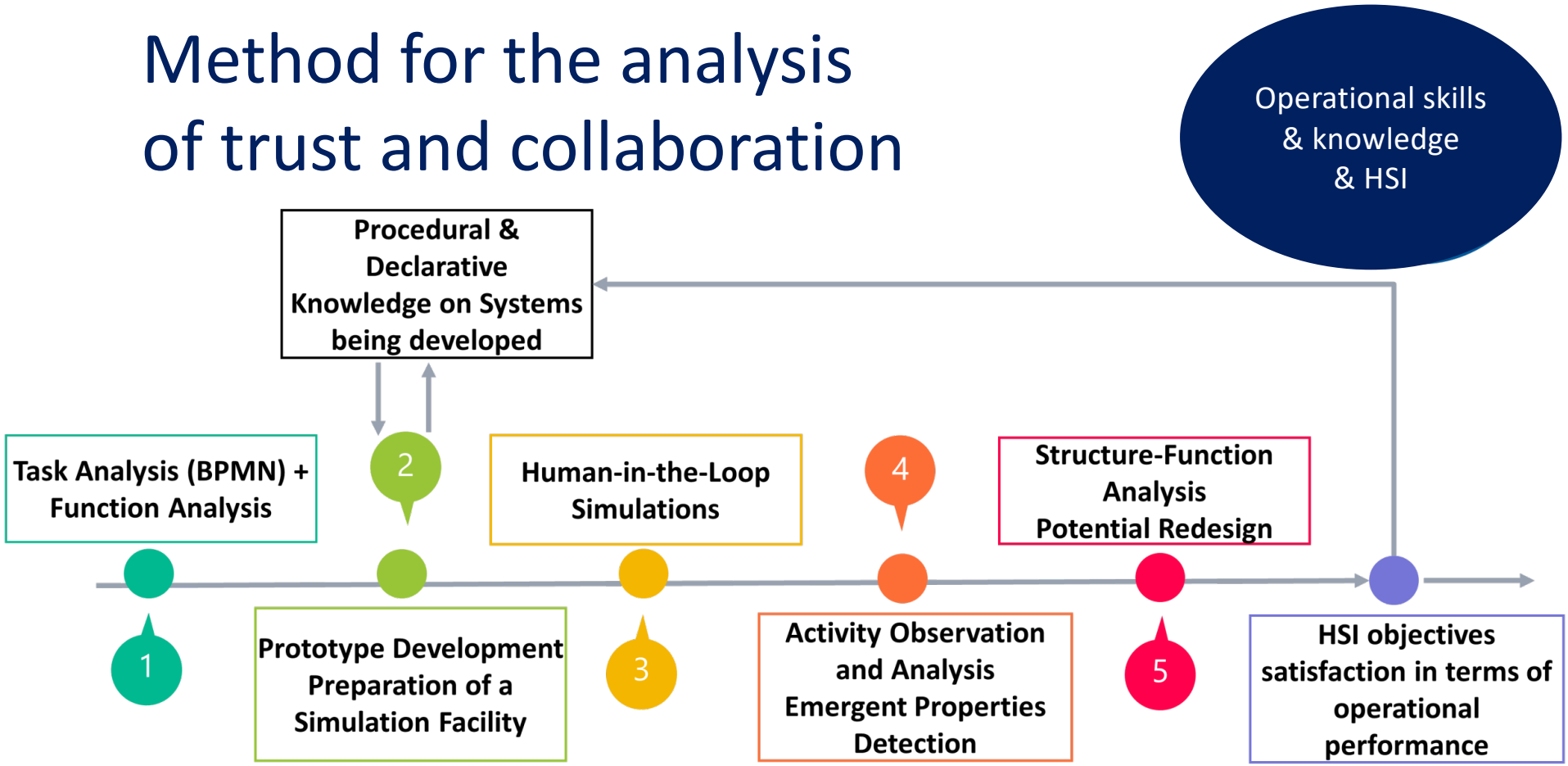
- Propose and test a method to evaluate the performance of pilot–virtual assistant teaming…

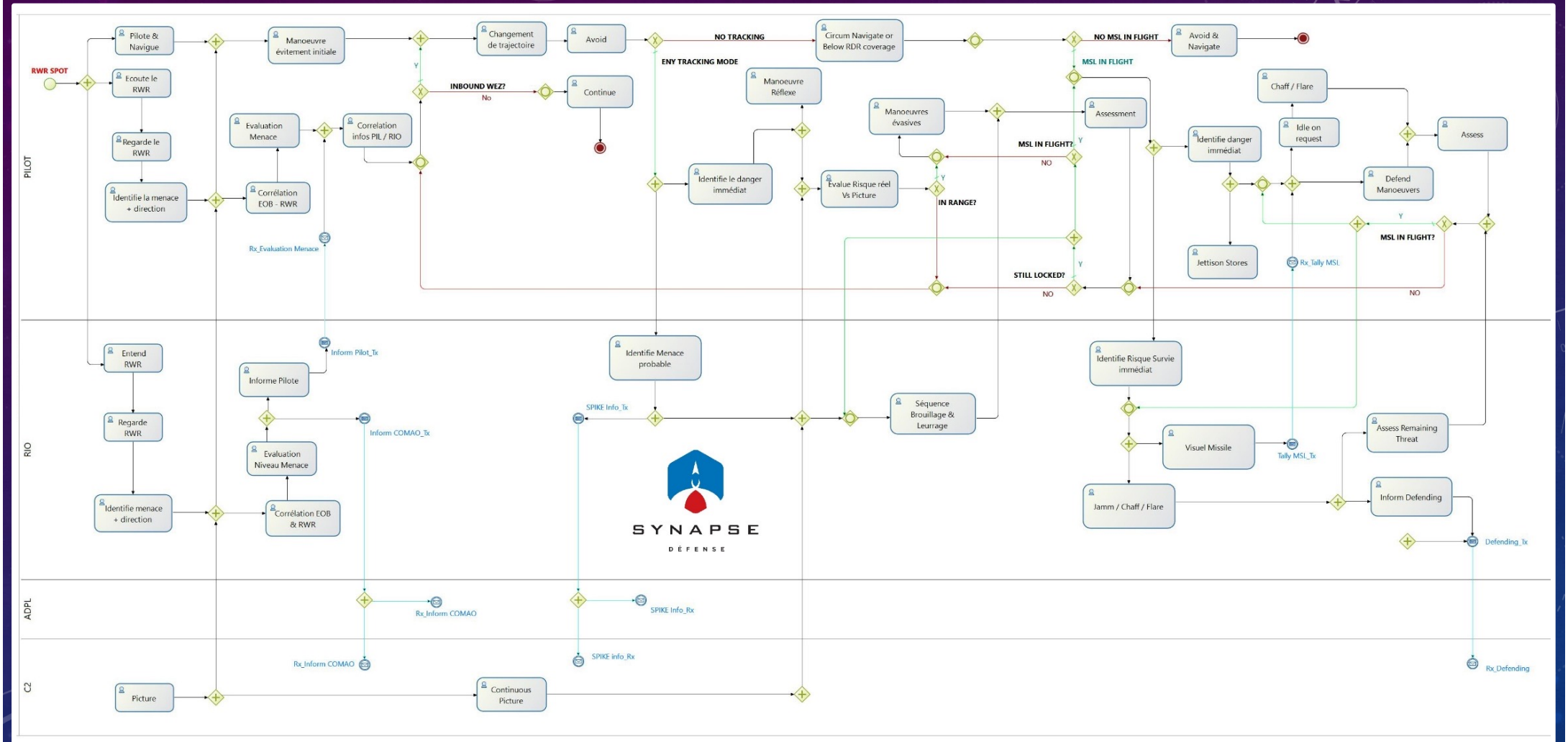
  … in the cockpit of a simulated fighter aircraft

- Define trust and collaboration models & metrics by
  - Considering pilot's context and environment
  - Building indicators based on operational experience
  - Building metrics based on tangible virtual prototypes
  - Developing virtual prototypes (virtual assistant) and experiments

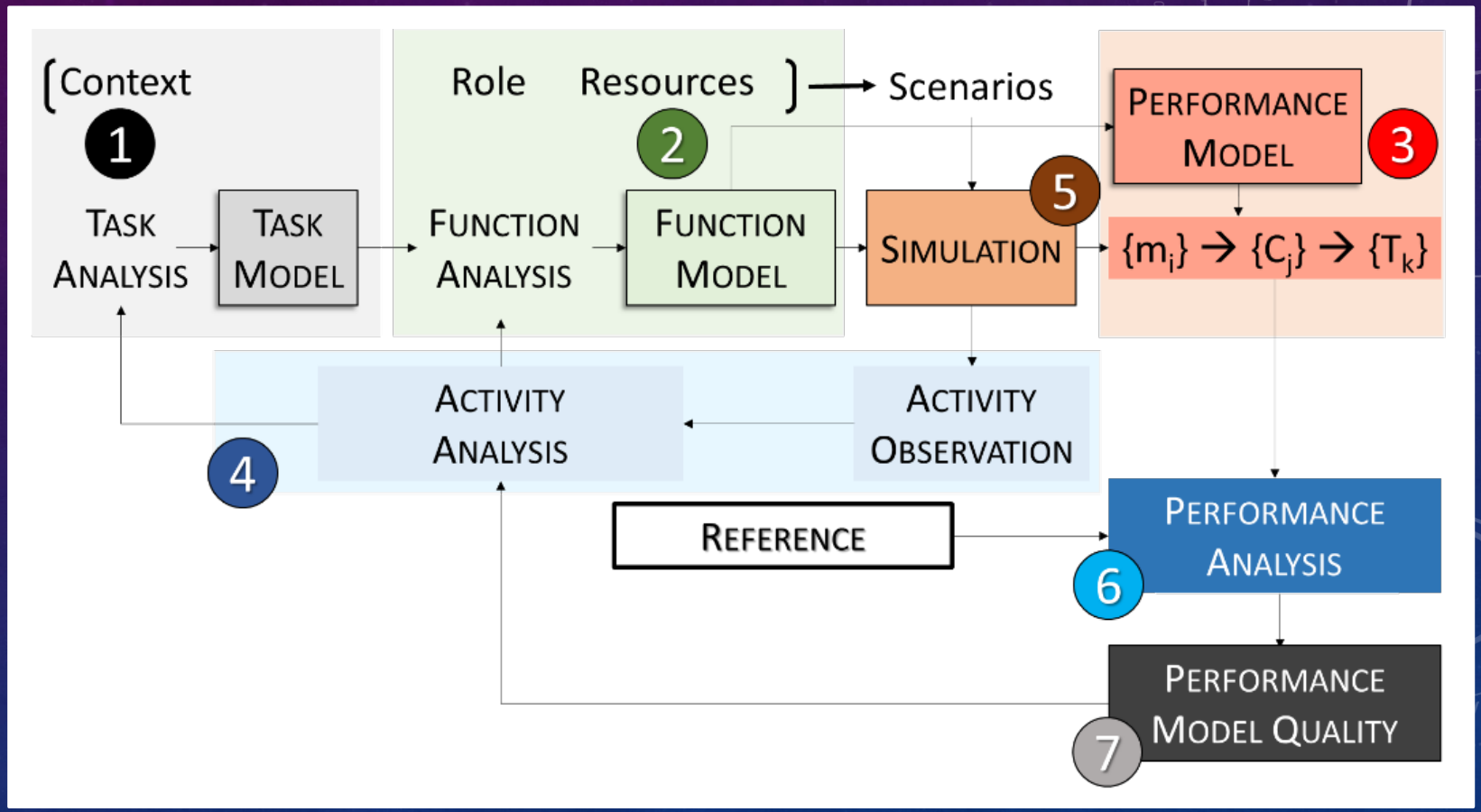
Human-Machine Teaming

Method for the analysis of trust and collaboration




PILOT
RIO
ADPL
C2
RWR SPOT
Pilote & Navigue
Ecoute le RWR
Regarde le RWR
Identifie la menace + direction
Manoeuvre évitement initiale
Evaluation Menace
Corrélation EOB - RWR
Correlation infos PIL / RIO
Rx_Evaluation Menace
Changement de trajectoire
Avoid
INBOUND WEZ?
No
Continue
NO TRACKING
ENY TRACKING MODE
Circum Navigate or Below RDR coverage
Manoeuvre Réflexe
Identifie le danger immédiat
Evalue Risque réel Vs Picture
IN RANGE?
Manoeuvres évasives
NO MSL IN FLIGHT
Avoid & Navigate
MSL IN FLIGHT
Assessment
MSL IN FLIGHT?
NO
STILL LOCKED?
Identifie danger immédiat
Chaff / Flare
Idle on request
Assess
Defend Manoeuvers
Jettison Stores
Rx_Tally MSL
Entend RWR
Regarde RWR
Identifie menace + direction
Informe Pilote
Inform Pilot_Tx
Evaluation Niveau Menace
Corrélation EOB & RWR
Inform COMAO_Tx
Identifie Menace probable
SPIKE Info_Tx
Séquence Brouillage & Leurrage
Identifie Risque Survie immédiat
Visuel Missile
Tally MSL_Tx
Jamm / Chaff / Flare
Assess Remaining Threat
Inform Defending
Defending_Tx
SYNAPSE
DÉFENSE
Rx_Inform COMAO
SPIKE Info_Rx
SPIKE info_Rx
Rx_Inform COMAO
Rx_Defending
Picture
Continuous Picture

MOHICAN PRODEC

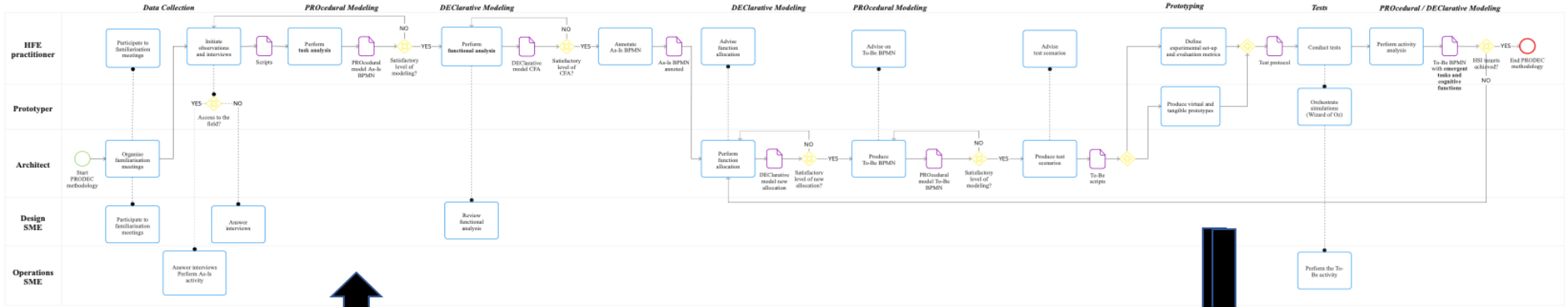


Task-based Procedural Knowledge → Task-based Declarative Knowledge → Emergence & Activity Analysis

AS-IS

TO-BE

Human-in-the-loop simulations



TO-BE becomes AS-IS ← TO-BE

Activity-based Procedural Knowledge

+

+

ADD – ON
DECISION
SUPPORT JOBS

SIMULATION SET-UP


SYNAPSE
DÉFENSE
TGT1 245°/7Nm
POSIT MOHS
16°/7Nm
08:31:47

CAPTURE AND ANALYSIS TOOLS

Heart rate monitor : GARMIN watch

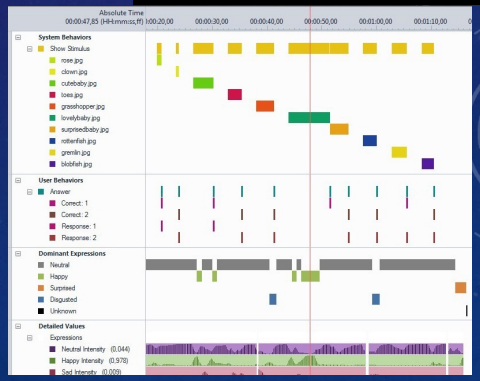
- More reliable than wrist measurement
- Less intrusive

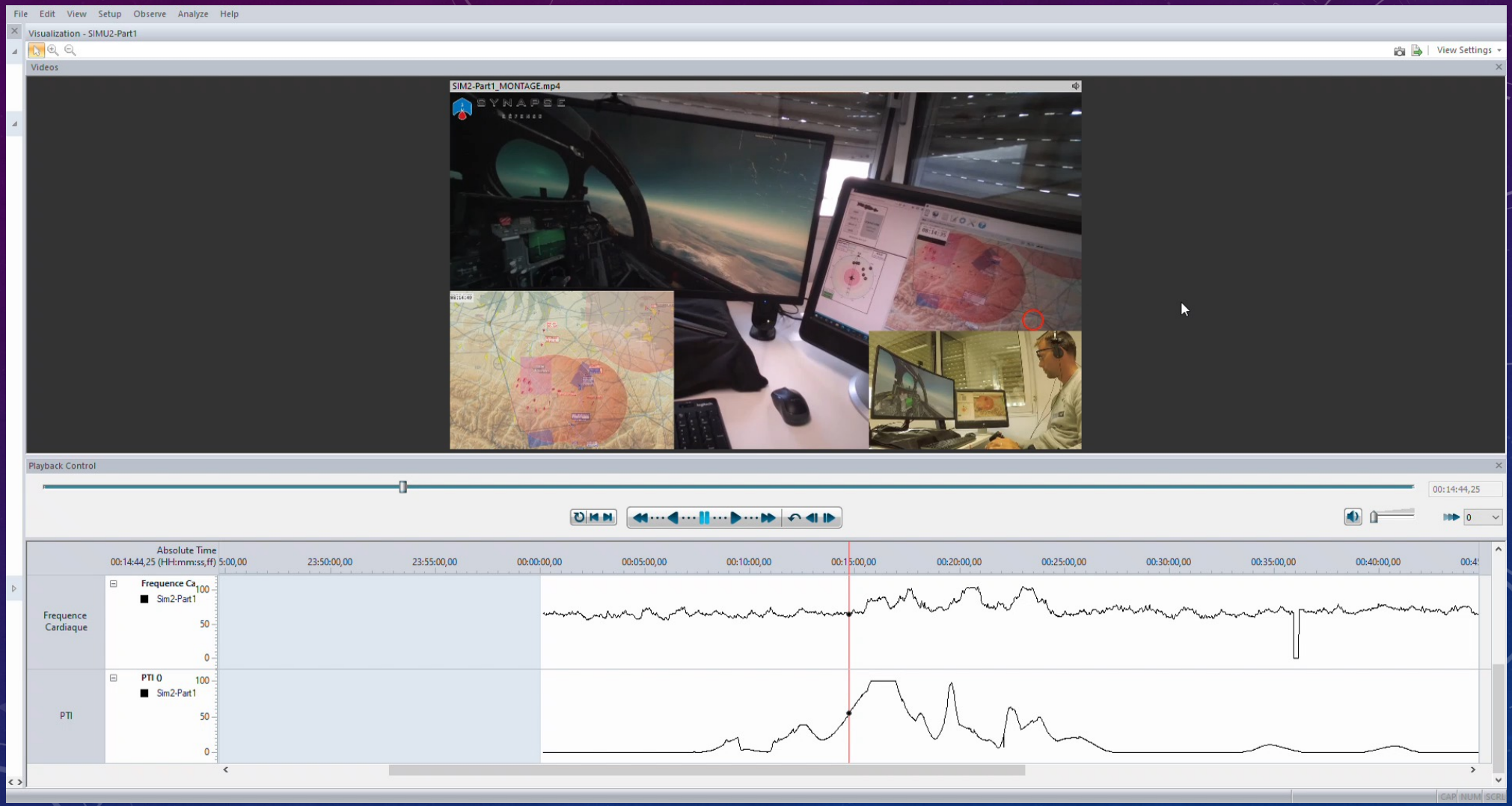
Eye tracking : Tobii glasses

- Goal: record in real time, user's eye gaze on screens

Noldus XT Observer

- Allows the observation of uses to be instrumented
- Represents behaviors in an accurate and quantitative manner
- Integrates behavioral and physiological data
- Create video clips of the most interesting data
- Create video clips of the most interesting data

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Visualization - SIMU2-Part1
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SIM2-Part1_MONTAGE.mp4
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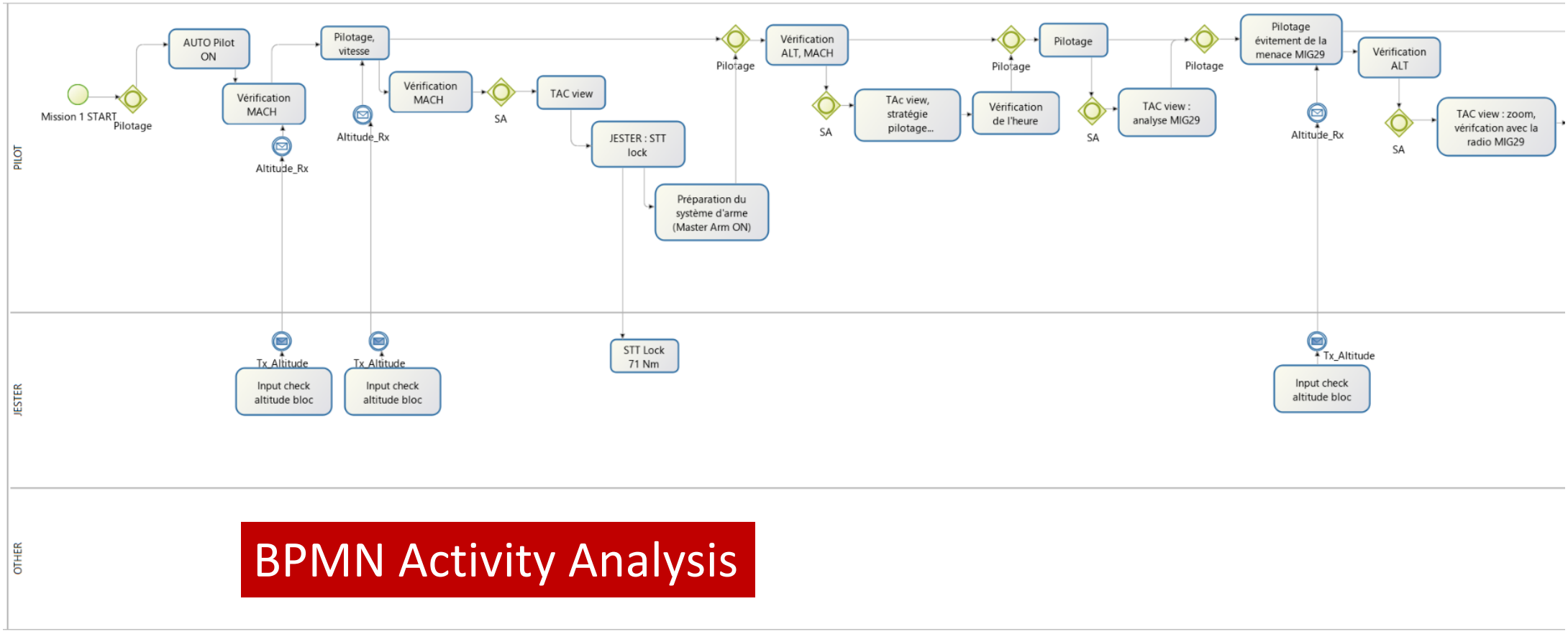
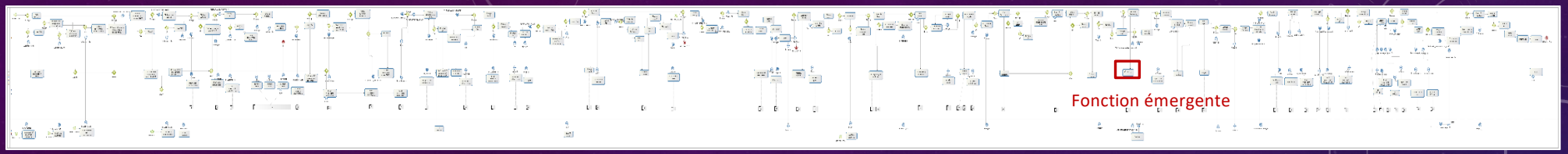
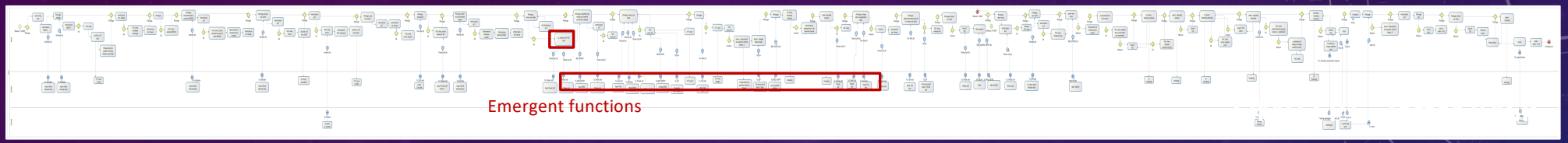
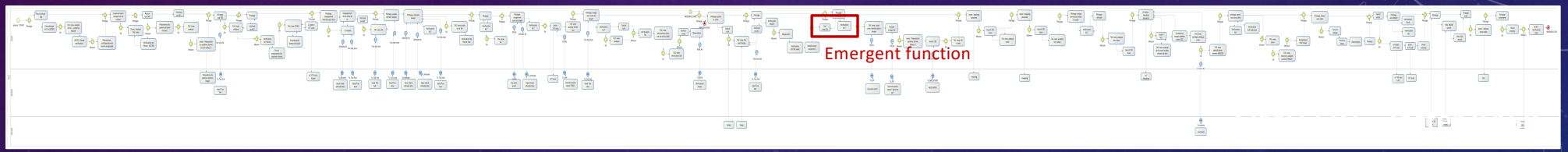
Sim2-Part1

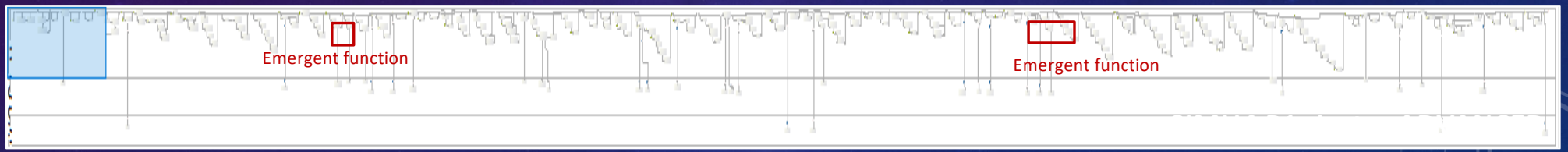


BPMN Activity Analysis



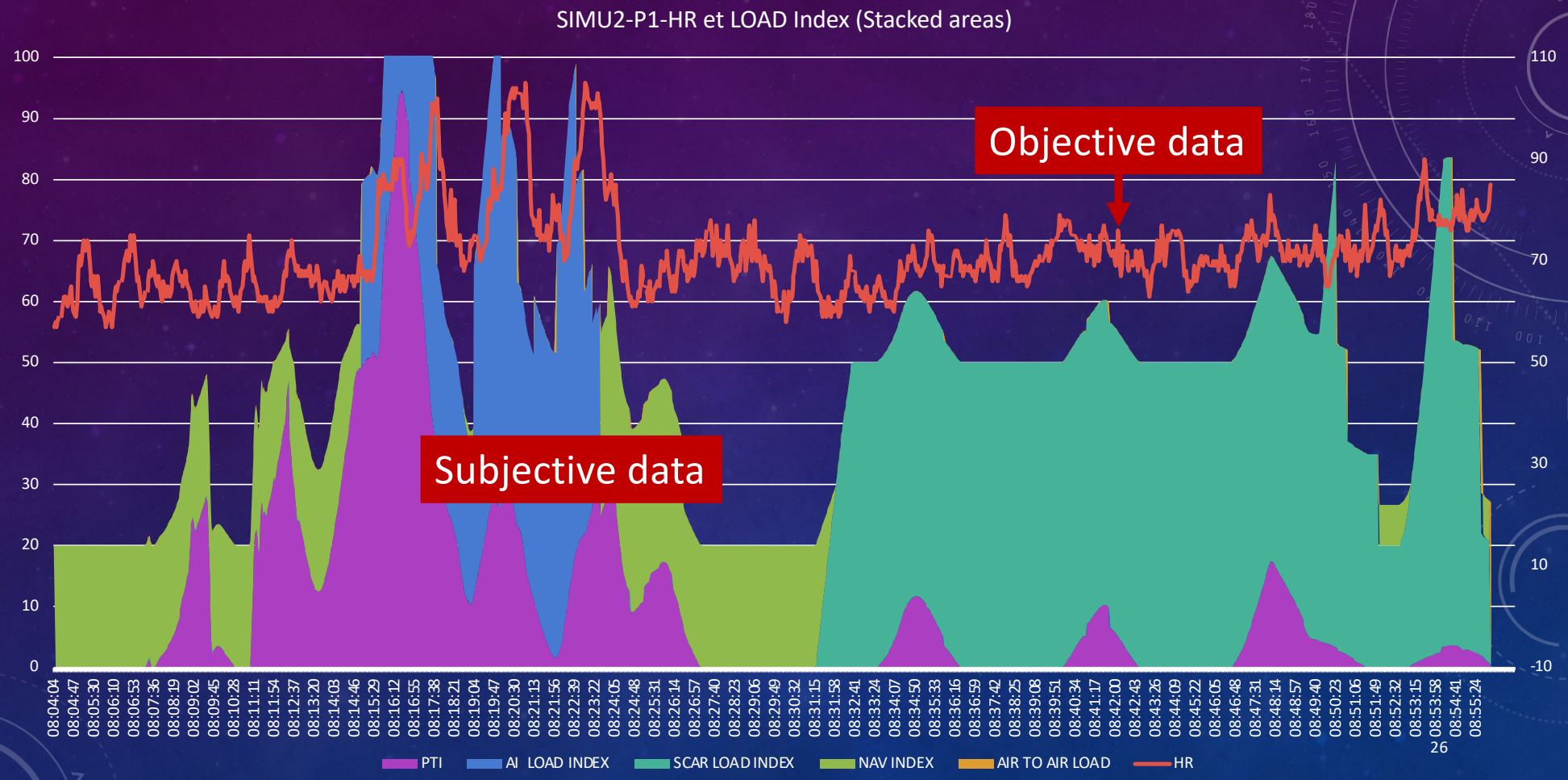




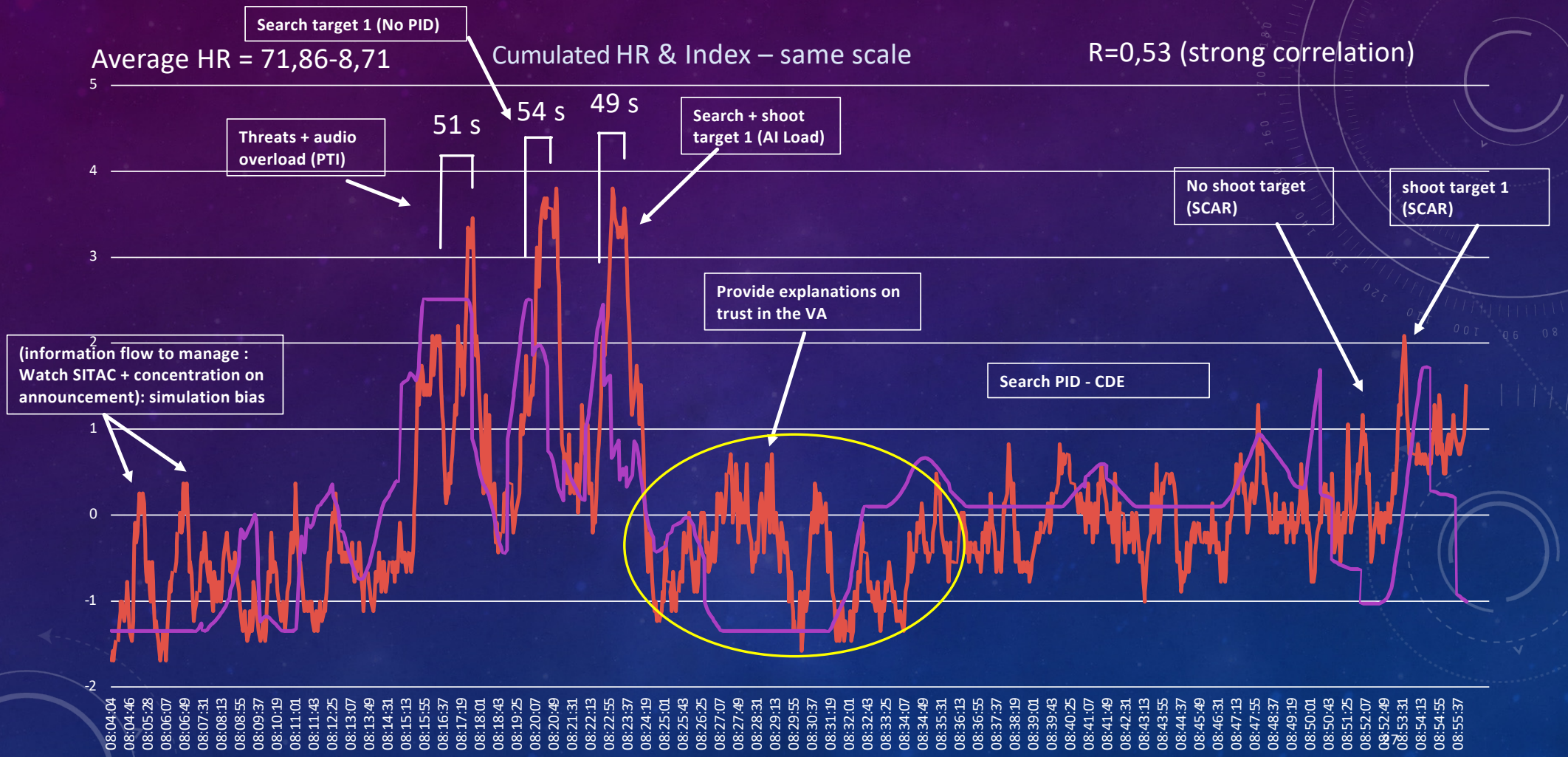


BPMN ACTIVITY ANALYSIS +

CORRELATION BETWEEN PILOT LOAD INDEX AND CFA RESULTS



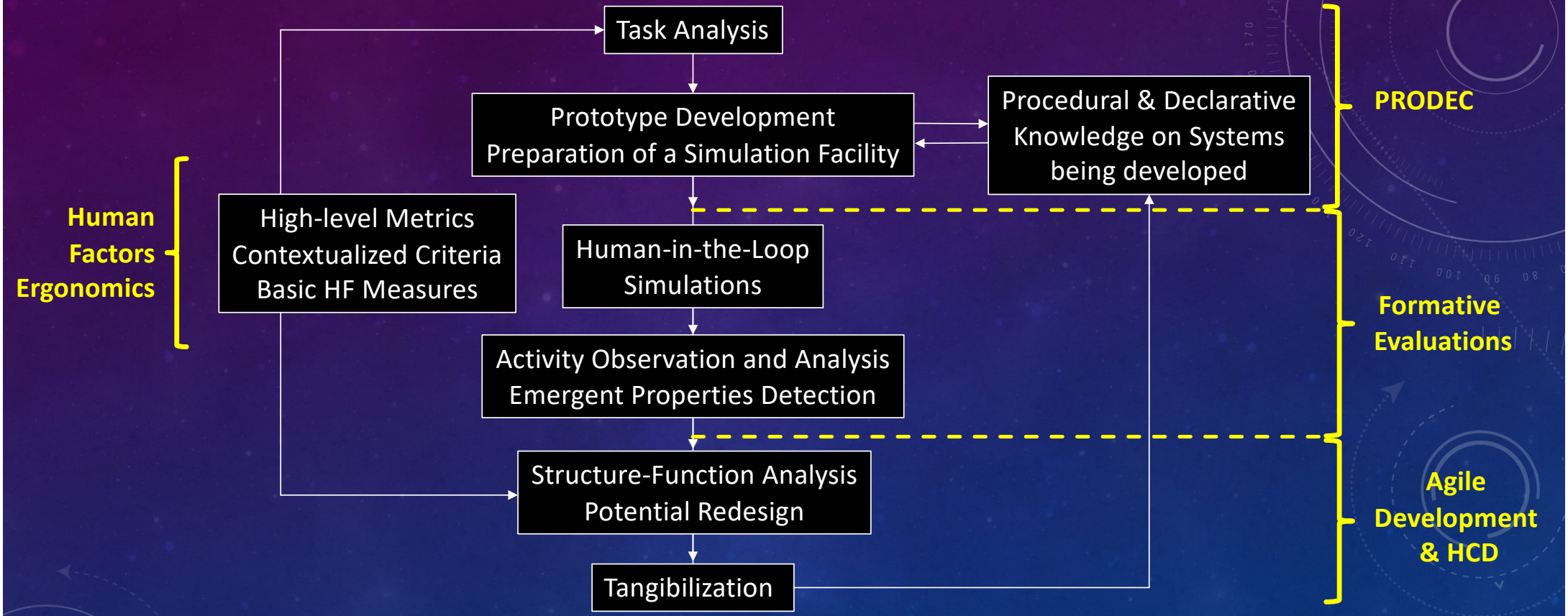
CORRELATION BETWEEN PILOT LOAD INDEX AND CFA RESULTS



ELICITATION & VALIDATION OF EVALUATION CRITERIA

Metrics	Criteria	Measures
Trust	Efficiency	Processed information (pilot actions)
		Verified information (eye tracking)
	Effectivity	Interaction time (Raw data - The Observer XT)
	Reliability/Robustness	Bug or functional default (experimenter)
	Relevance	Added value (pilot)
	Transparency	Perceived information (pilot)
		Interpretated/comprehended information (pilot)
	Flexibility/Adaptability	Adaptability to the pilot or to context (pilot)
Collaboration	Feedback quality	Quantity & nature of VA feedback (pilot)
	Perceived relief of the task	Perceived relief of pilot's workload (pilot)
	No discomfort	Discomfort introduced by usage/announcement (pilot)

DISCUSSIONS & PERSPECTIVES

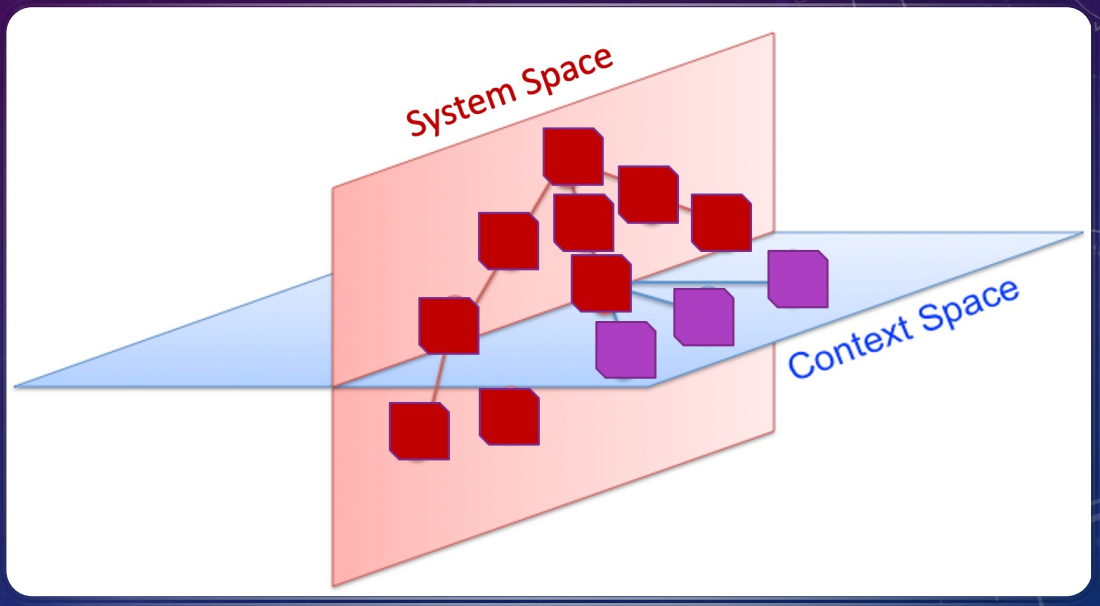


Systemic ontology development enables optimal definition of HSI metrics (e.g., trust, collaboration & operational performance)

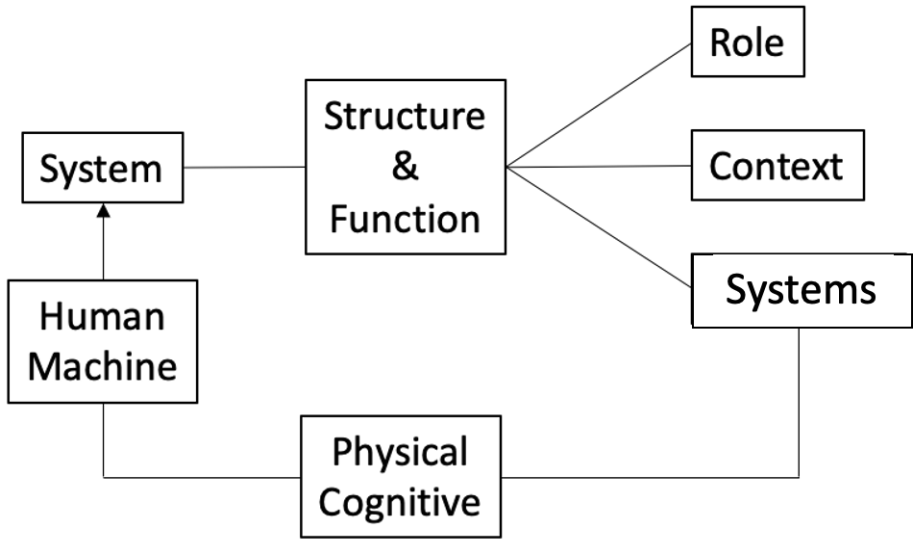
WHAT IS FUNDAMENTAL HERE?

FIRST THING TO UNDERSTAND

- There is a structuring space
  → the System Space
- There is a functional space
  → the Context Space

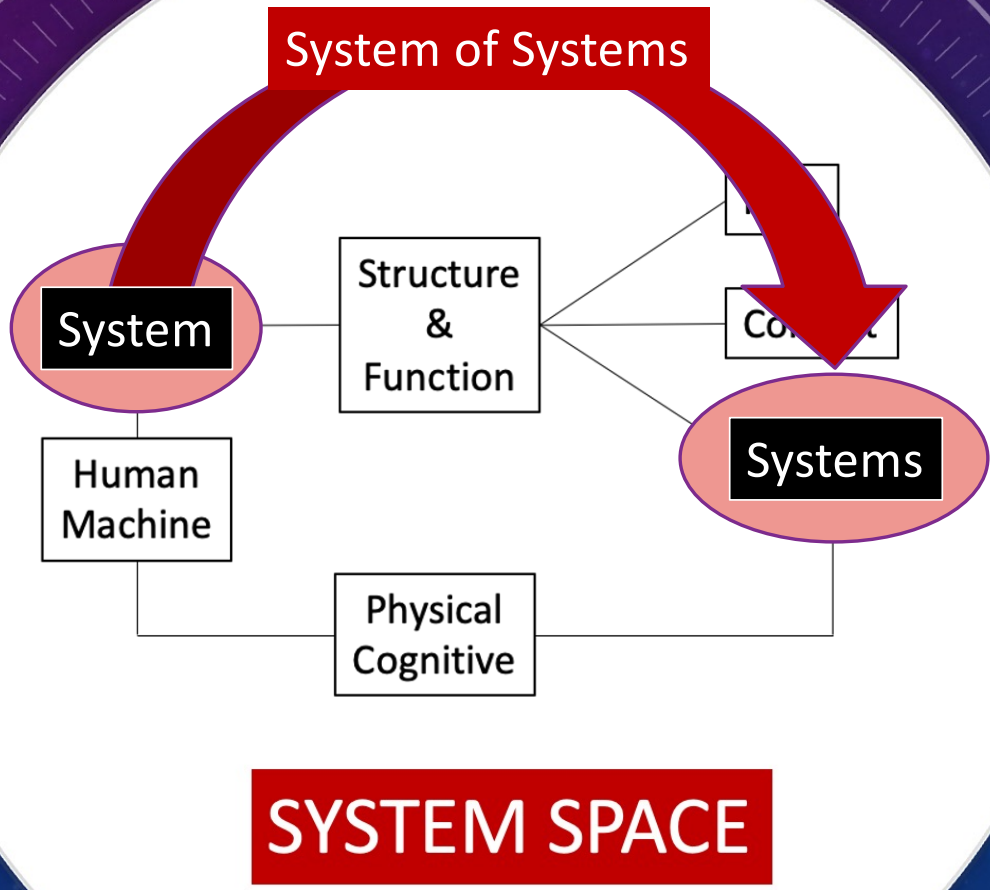


A SYSTEM REPRESENTING A DECLARATIVE ENTITY



SYSTEM SPACE

A SYSTEM REPRESENTING A DECLARATIVE ENTITY



A SYSTEM REPRESENTING A PROCEDURAL ENTITY

CONTEXT SPACE

OPERATIONS

PROCEDURAL SCENARIOS

CONTEXT ARCHITECTURE…

… SYSTEM ARCHITECTURE

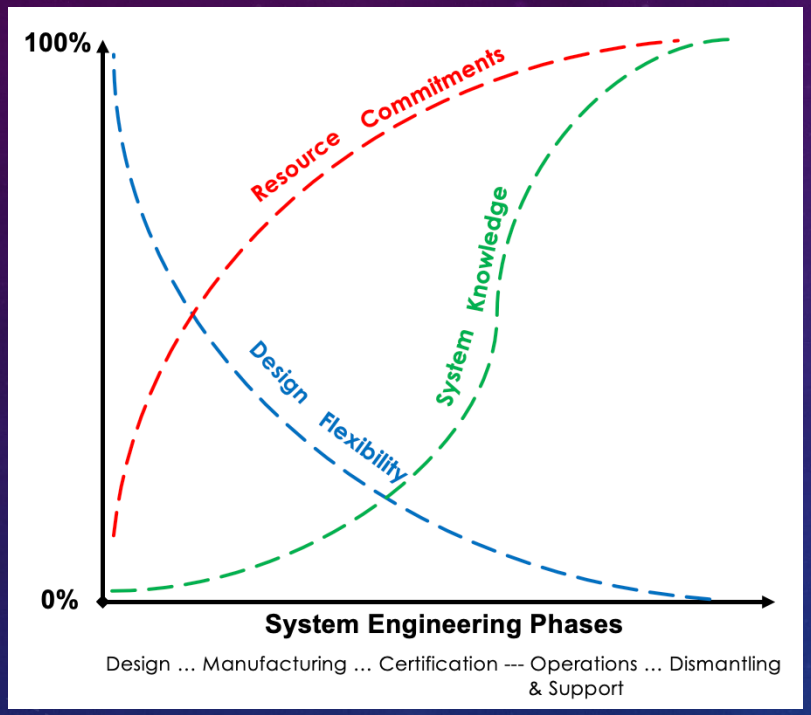
DECLARATIVE CONFIGURATIONS

ENGINEERING DESIGN

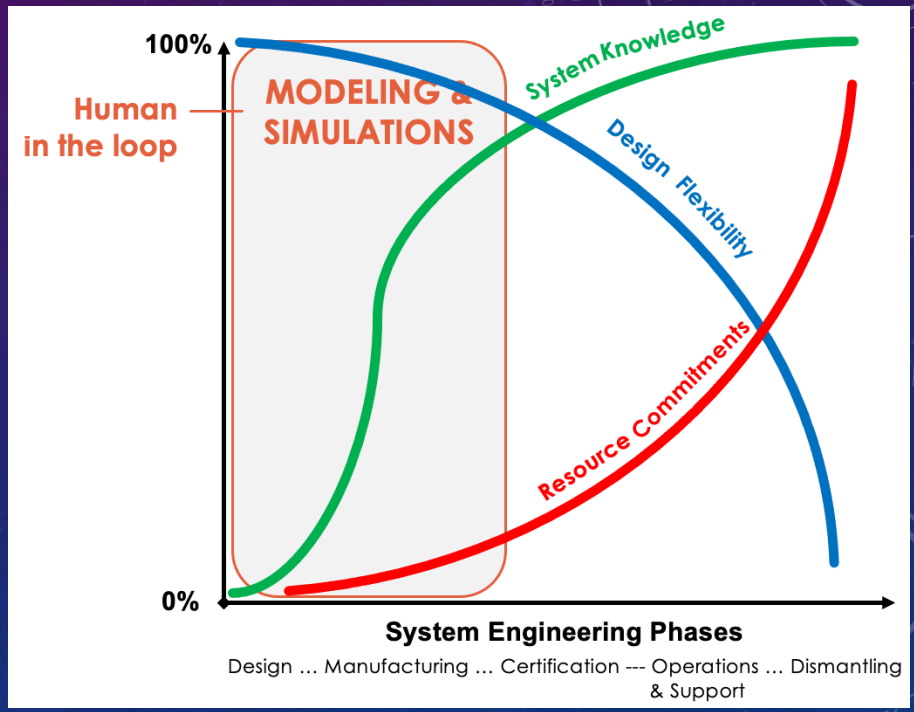
SCENARIO-BASED DESIGN…
…HUMAN-IN-THE-LOOP SIMULATION

LIFE-CYCLED HUMAN SYSTEMS INTEGRATION

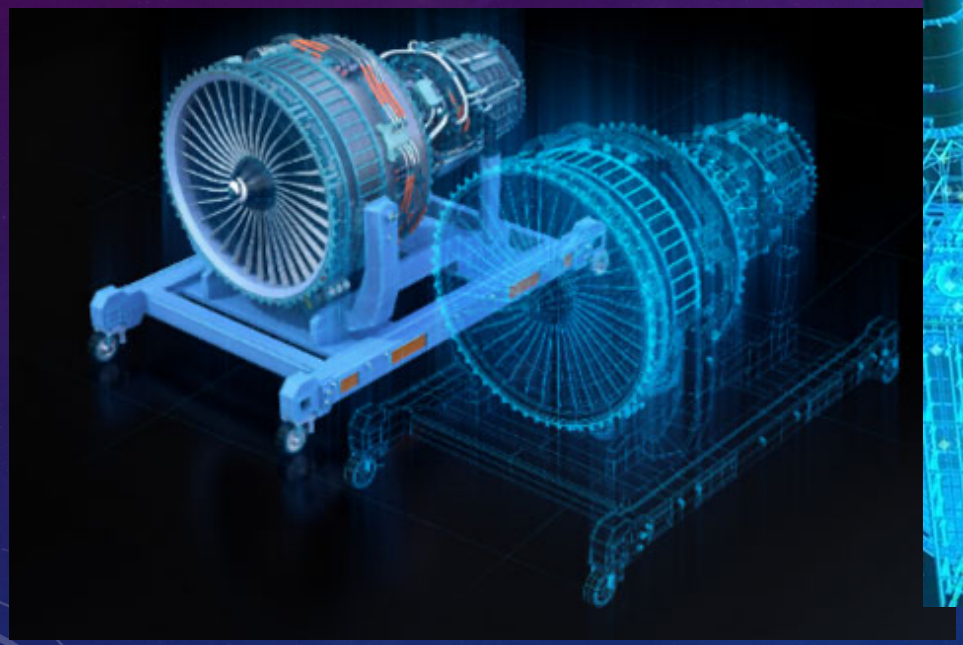
Technology-centered

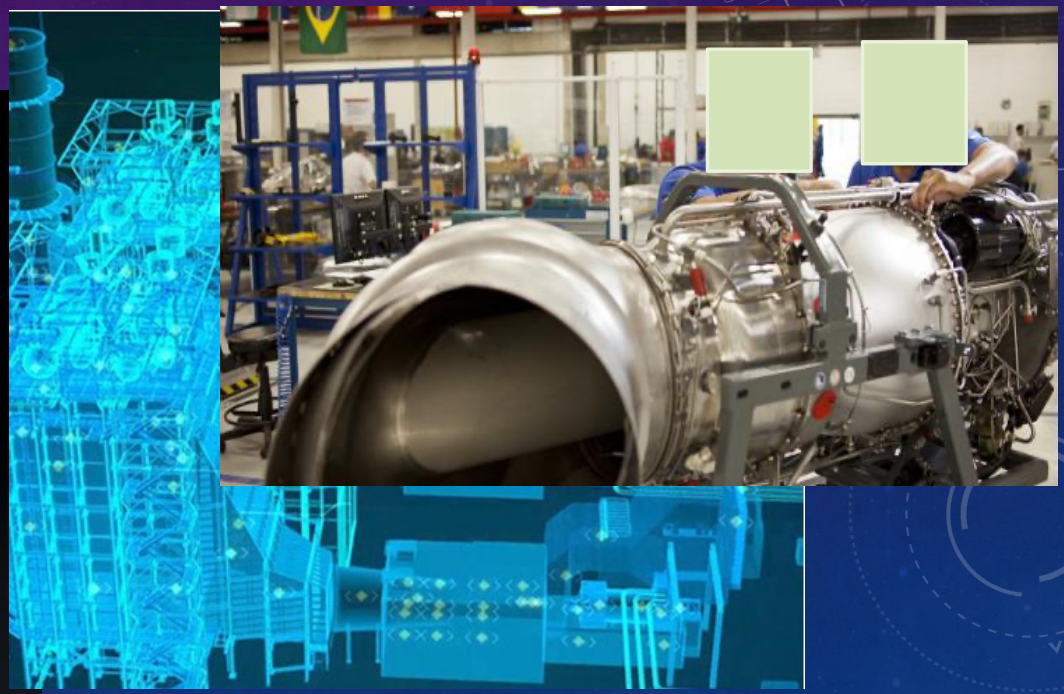


Human-centered



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





DIGITAL TWINS

Expanding HITLS

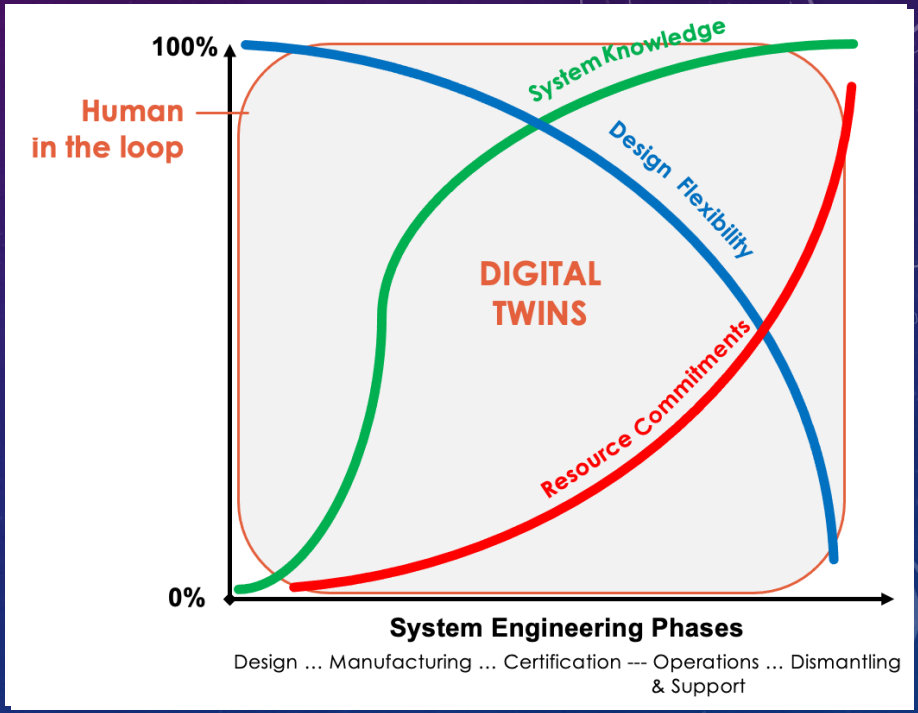
- During the whole life cycle
- “what if?”

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)

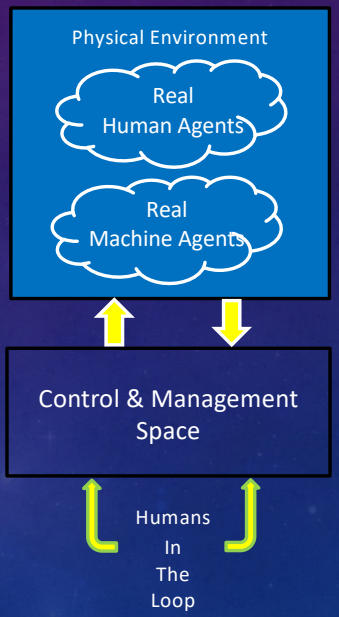
FROM MEANS TO PURPOSE

Engineering

Ergonomics & Automation

Human Factors

Tangible
Human-Centered Engineering

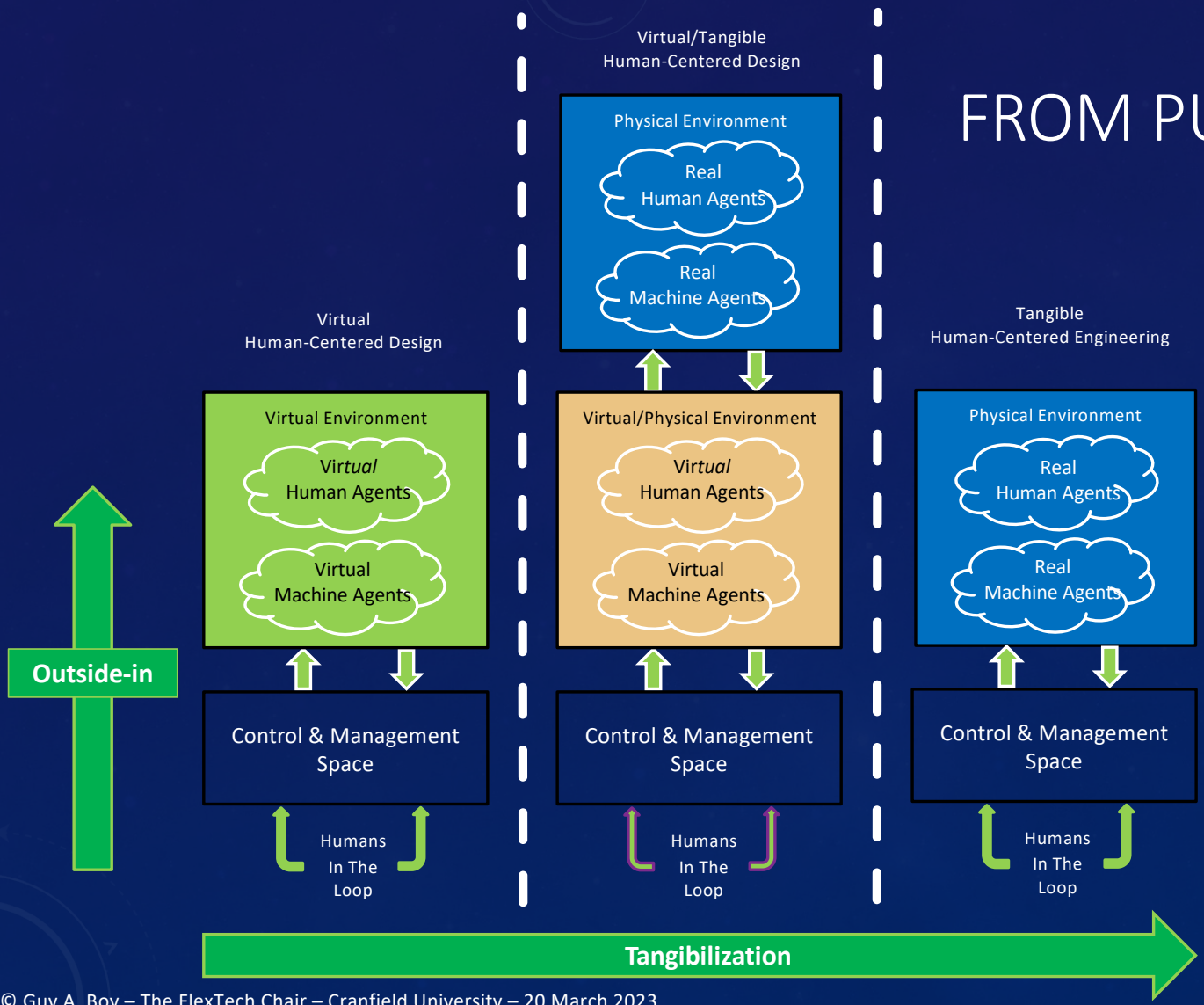


Inside-out

20th century approach

Engineering, Ergonomics, HCI & Automation

FROM PURPOSE TO MEANS



21ST CENTURY APPROACH

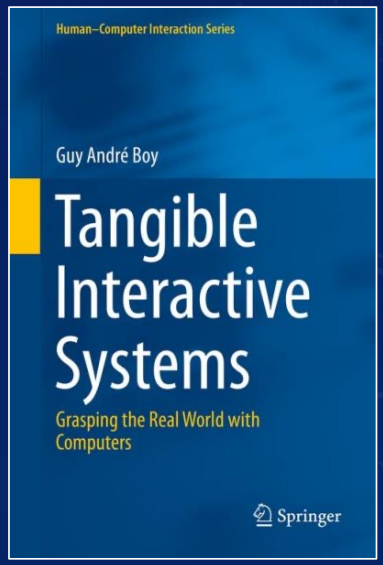
HSI

PHYSICAL & FIGURATIVE 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



MATURITY = READINESS LEVELS

TRL: Technology

MATURITY = READINESS LEVELS

HRL: 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

MATURITY = READINESS LEVELS

ORL: Organization

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

REFERENCES FOR THIS PRESENTATION

- Cognitive Function Analysis
- The Handbook of Human-Machine Interaction
- Orchestrating Human Centered Design
- Human Systems Integration
- Design for Flexibility
- Risk taking, Prevention & Design

- … be curious!

THANK YOU FOR YOUR ATTENTION…

I am open to questions…