HUMAN SYSTEMS INTEGRATION USE-CASES FROM VARIOUS INDUSTRIES

PROF. GUY ANDRÉ BOY

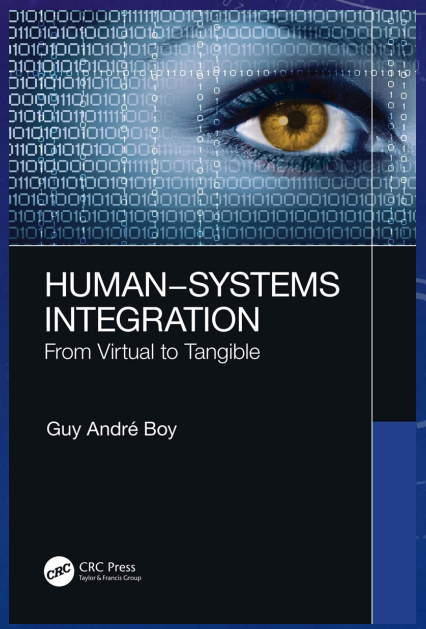
HUMAN SYSTEMS INTEGRATION

Illustrating on four industrial examples

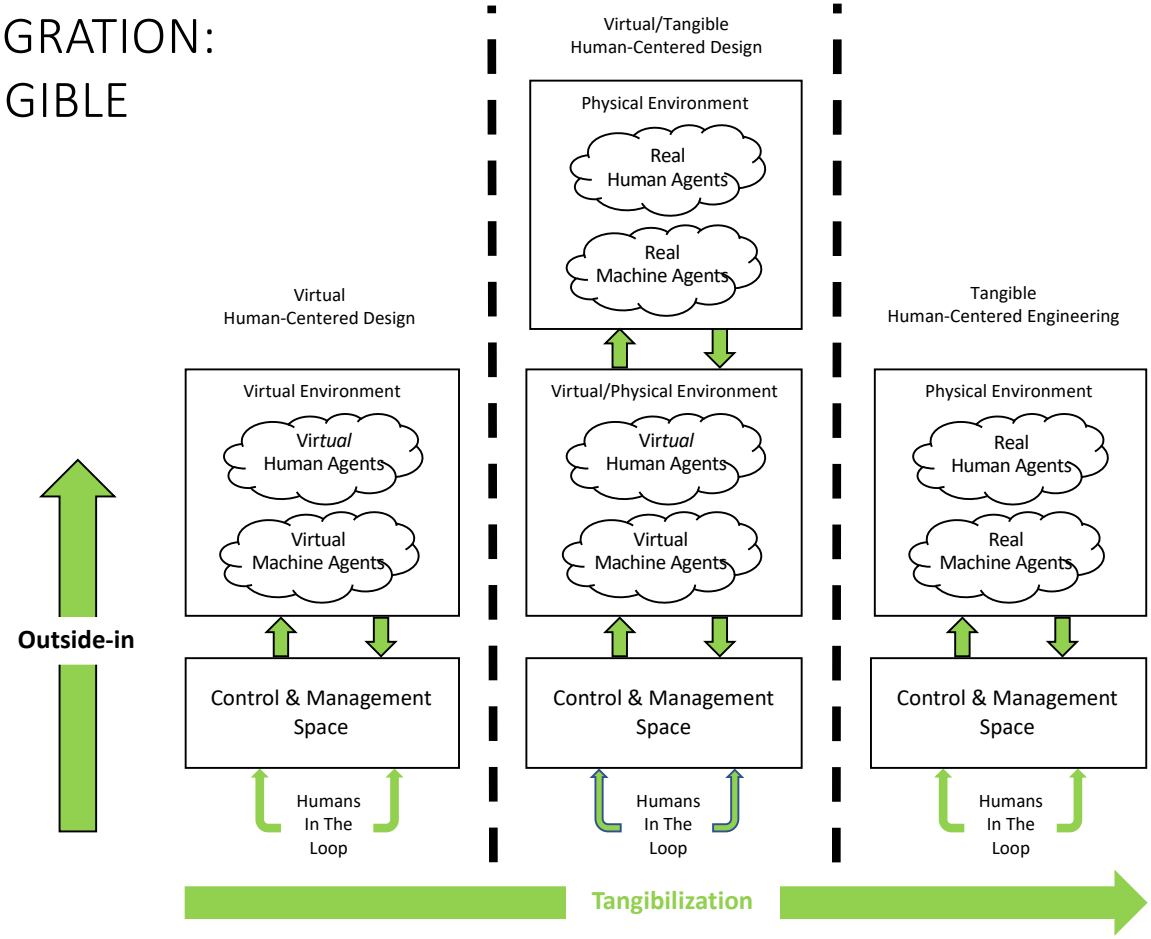
- Participatory design during the whole life cycle of a human-machine system
- Virtual human-centered automation & tangibility
- Task and activity analyses: taking emergence seriously

Anticipating the next two webinars

- Scenario-based design: the PRODEC experience
- Context in engineering design and operations



HUMAN SYSTEMS INTEGRATION: FROM VIRTUAL TO TANGIBLE



OUTLINE

- Introduction
- Use case 1: MOHICAN – Virtual assistant in air combat aircraft
- Use case 2: Oil-&-gas tele-robotics
- Use case 3: Remote maintenance of helicopter engines
- Use case 4: Remote and Virtual military air traffic control Center
- Other use cases
- Discussion

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USE CASE 1 – MOHICAN

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

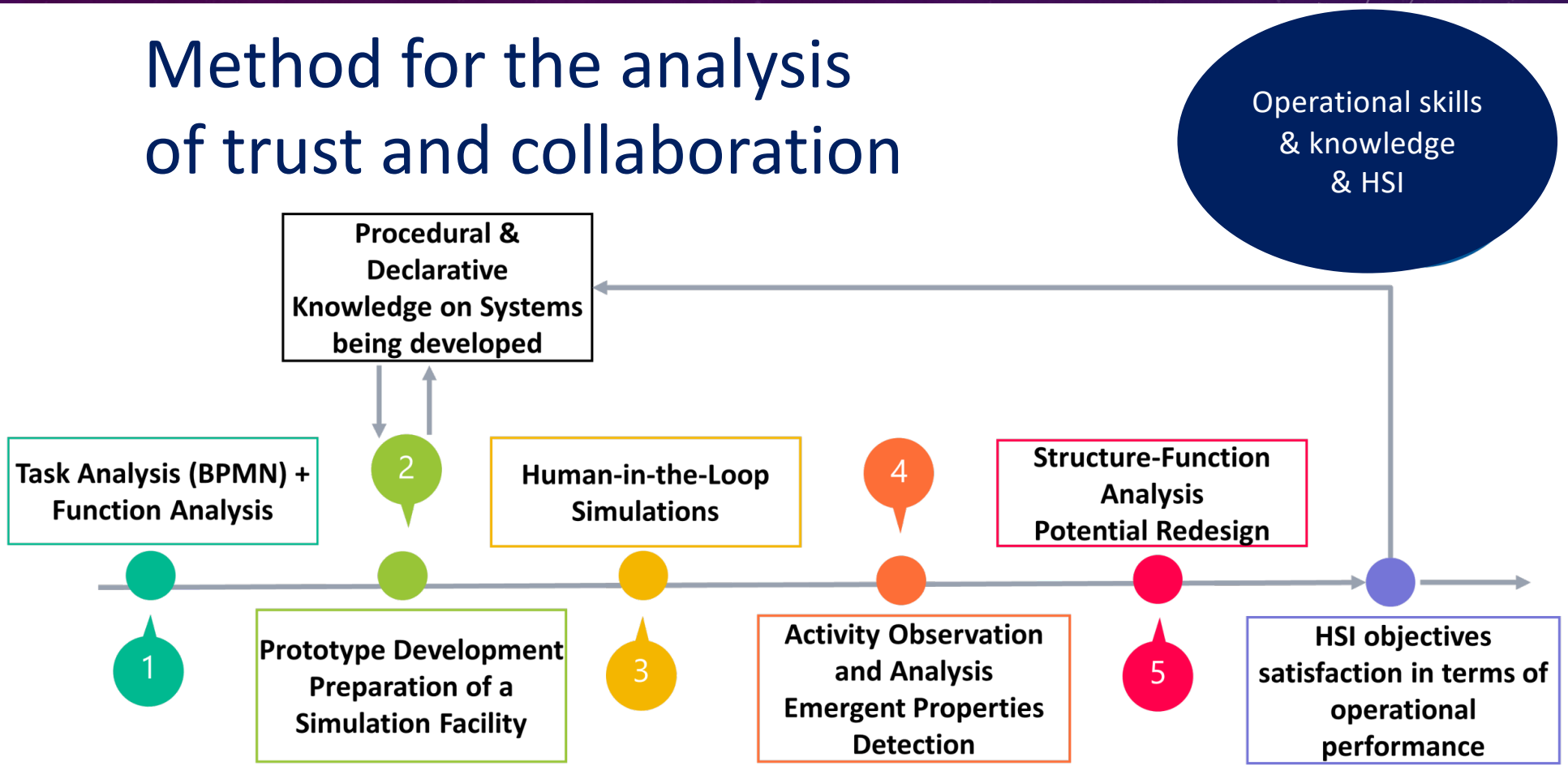
- Propose and test a method to evaluate the performance of pilot–virtual assistant teaming…

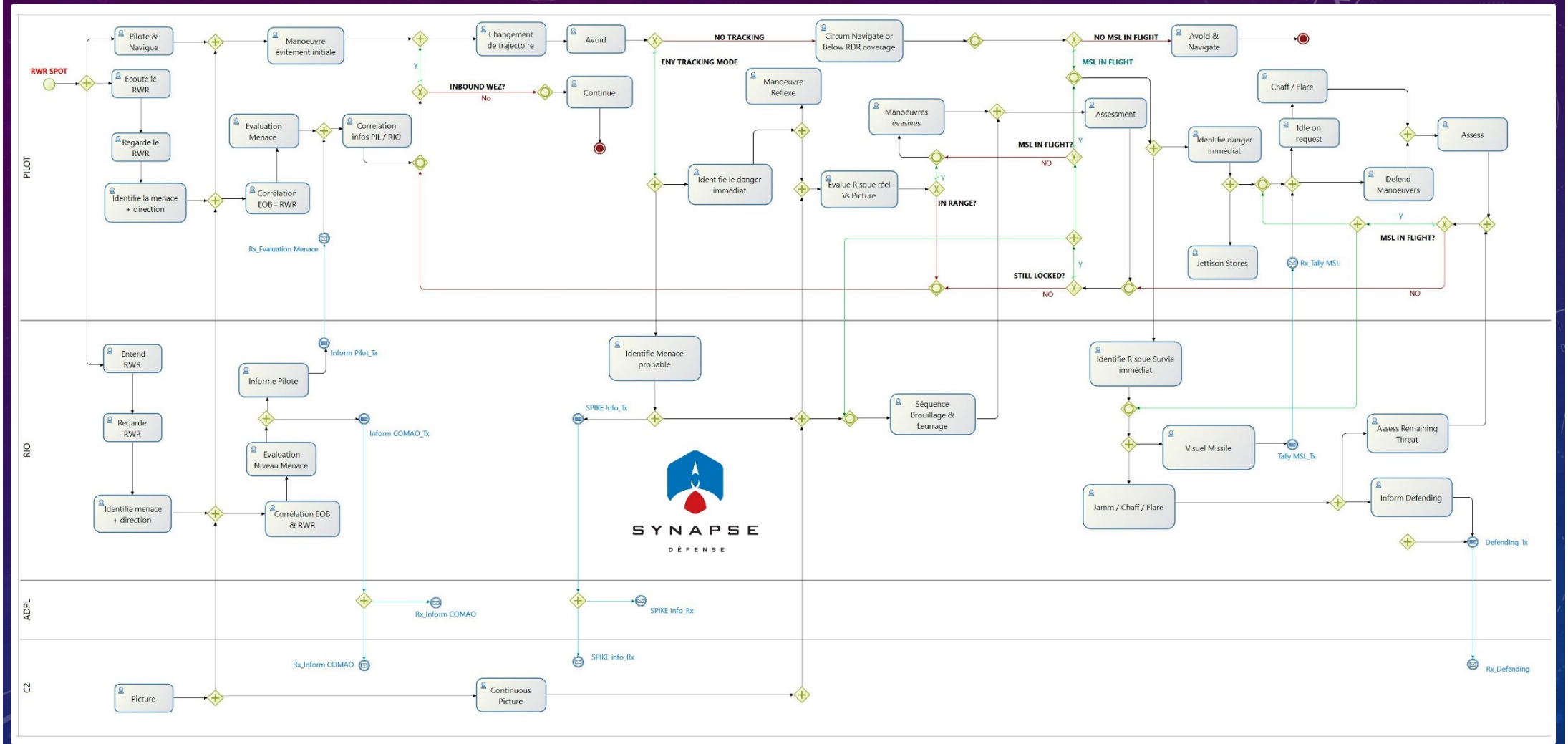
  … in the cockpit of a simulated fighter aircraft

- 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

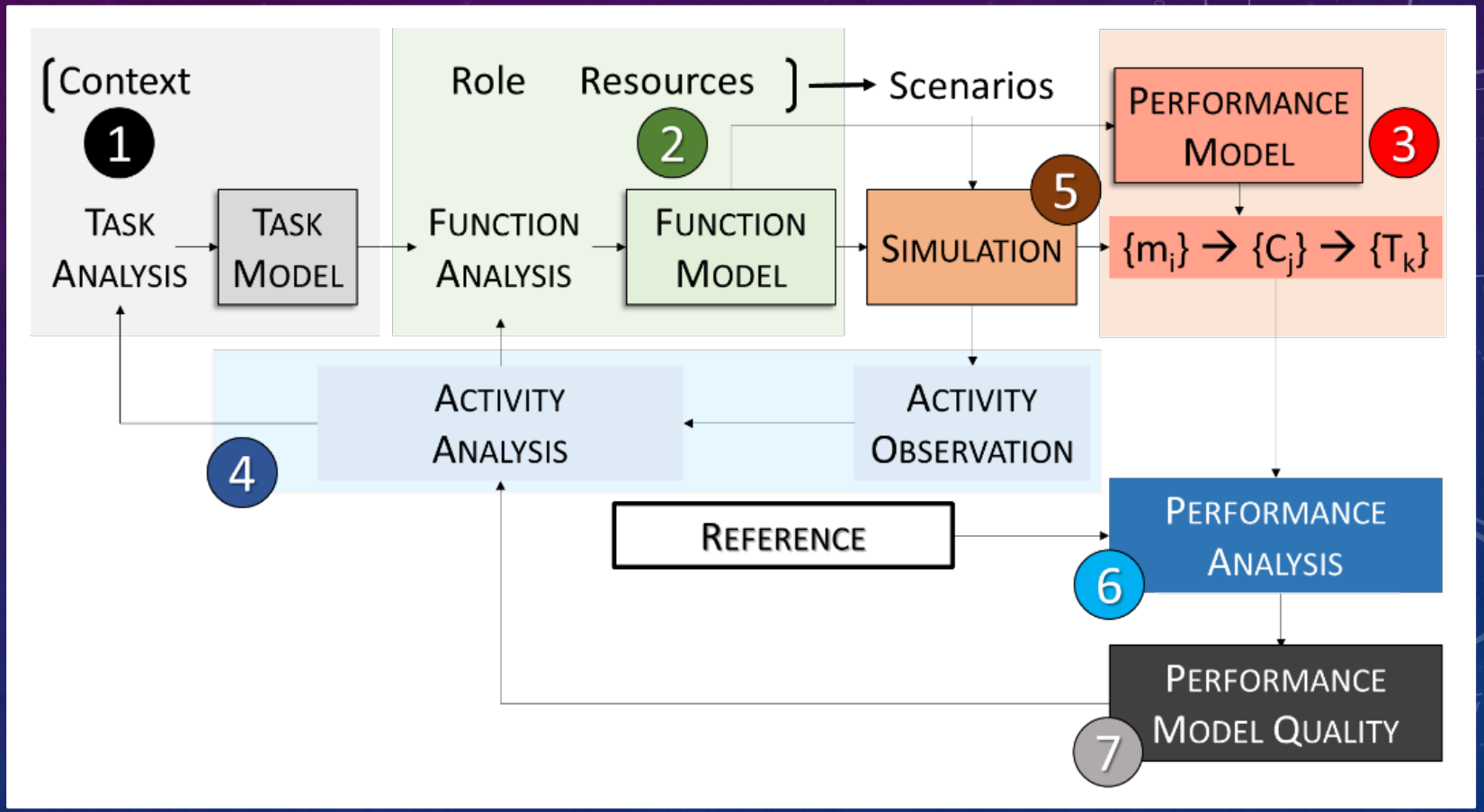
Human-Machine Teaming

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
INBOUND WEZ?
No
Continue
Avoid
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
MSL IN FLIGHT?
NO
NO MSL IN FLIGHT
Avoid & Navigate
MSL IN FLIGHT
Assessment
Identifie danger immédiat
Chaff / Flare
Idle on request
Assess
Defend Manoeuvers
Jettison Stores
Rx_Tally MSL
MSL IN FLIGHT?
STILL LOCKED?
Entend RWR
Regarde RWR
Identifie menace + direction
Corrélation EOB & RWR
Evaluation Niveau Menace
Informe Pilote
Inform Pilot_Tx
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

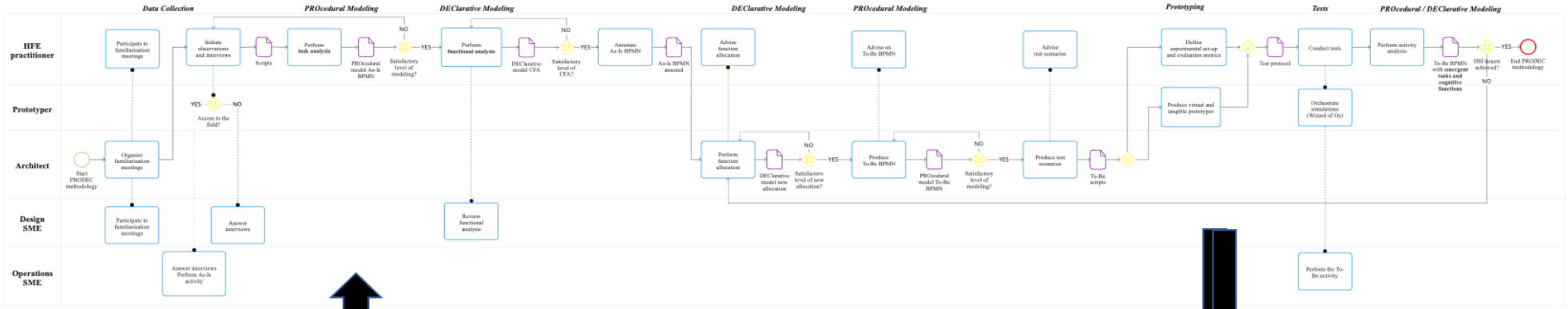


Task-based Procedural Knowledge → Task-based Declarative Knowledge → Emergence & Activity Analysis

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
DEFENSE
TGT1 246°/7Nm
POSIT MOHS
16°/77Nm
12

CAPTURE AND ANALYSIS TOOLS

Heart rate monitor : GARMIN watch

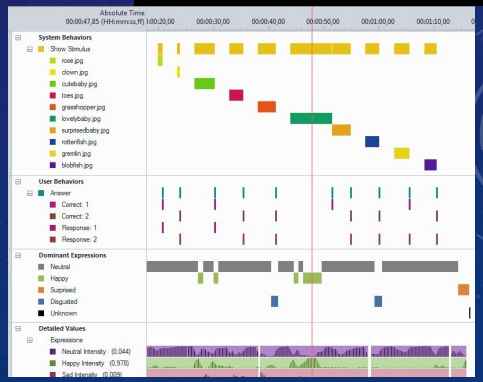
- More reliable than wrist measurement
- Less intrusive

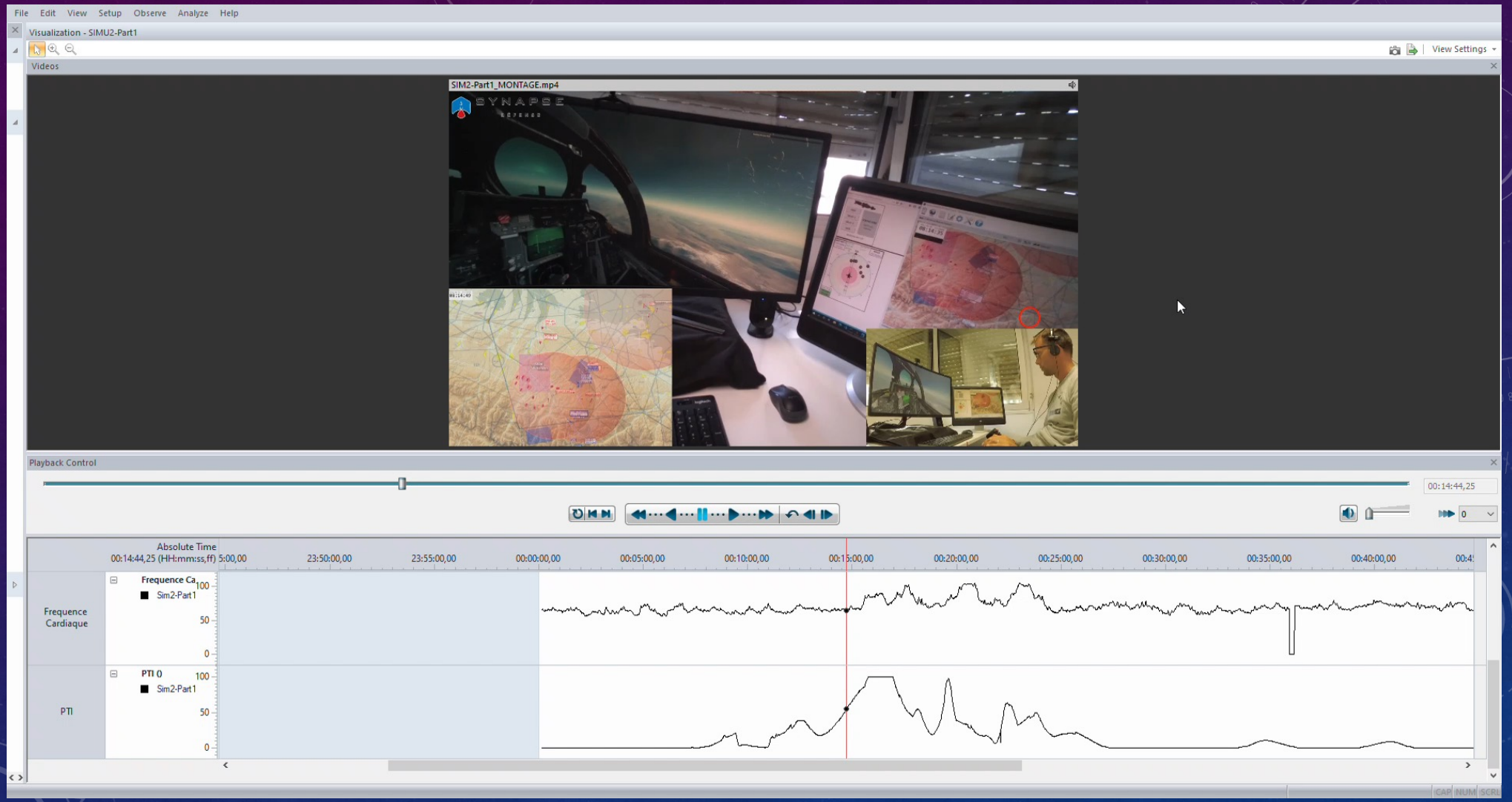
Eye tracking : Tobii glasses

- 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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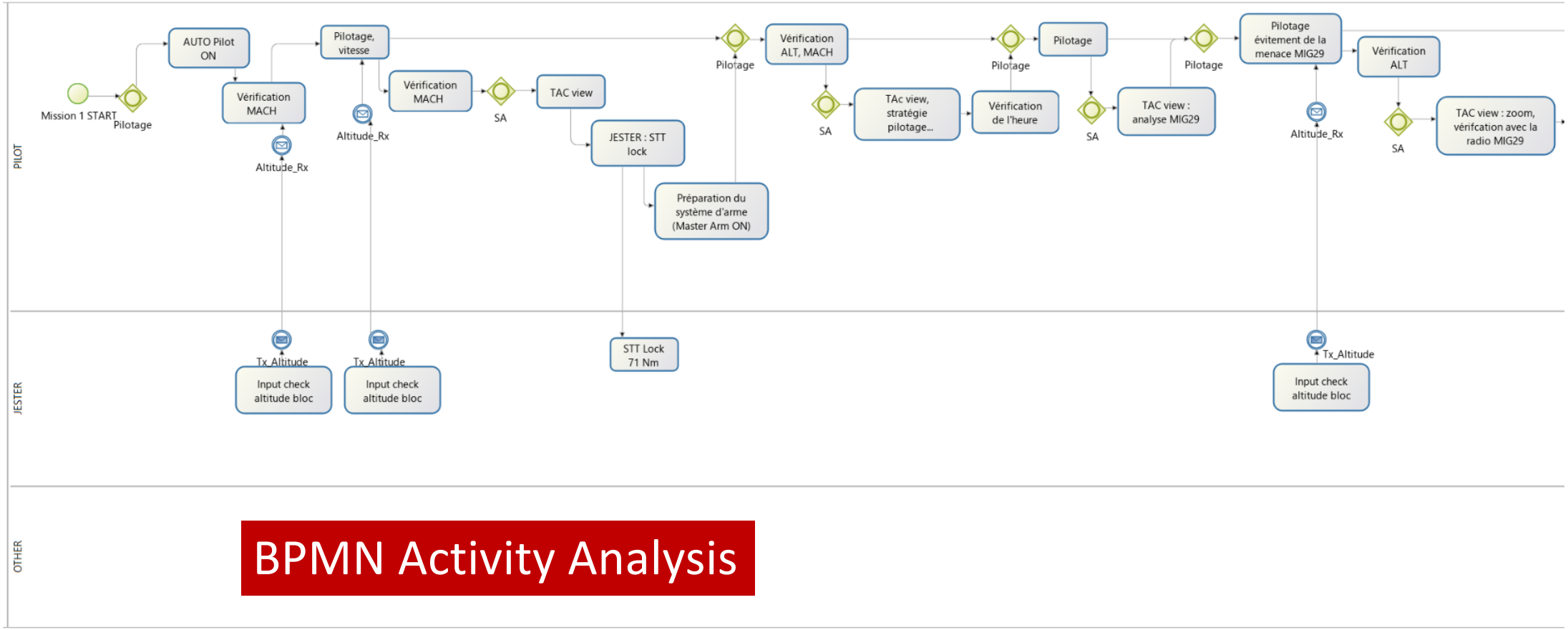
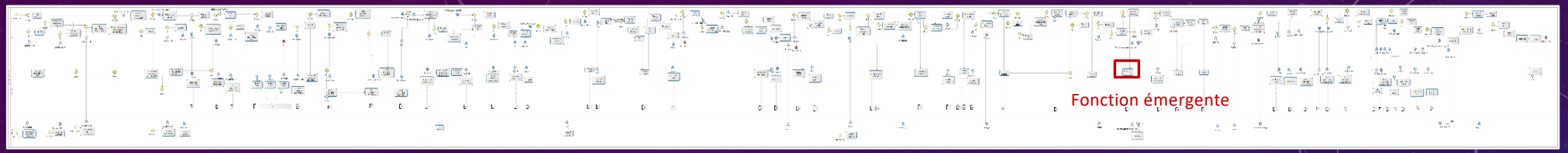
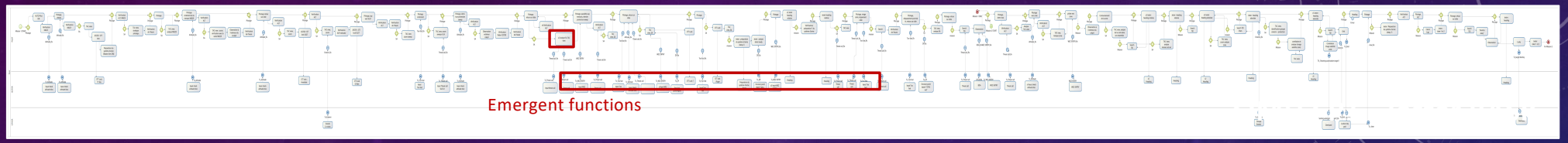
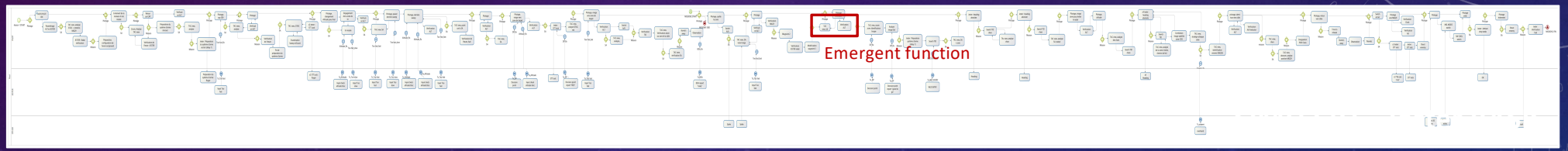


BPMN Activity Analysis

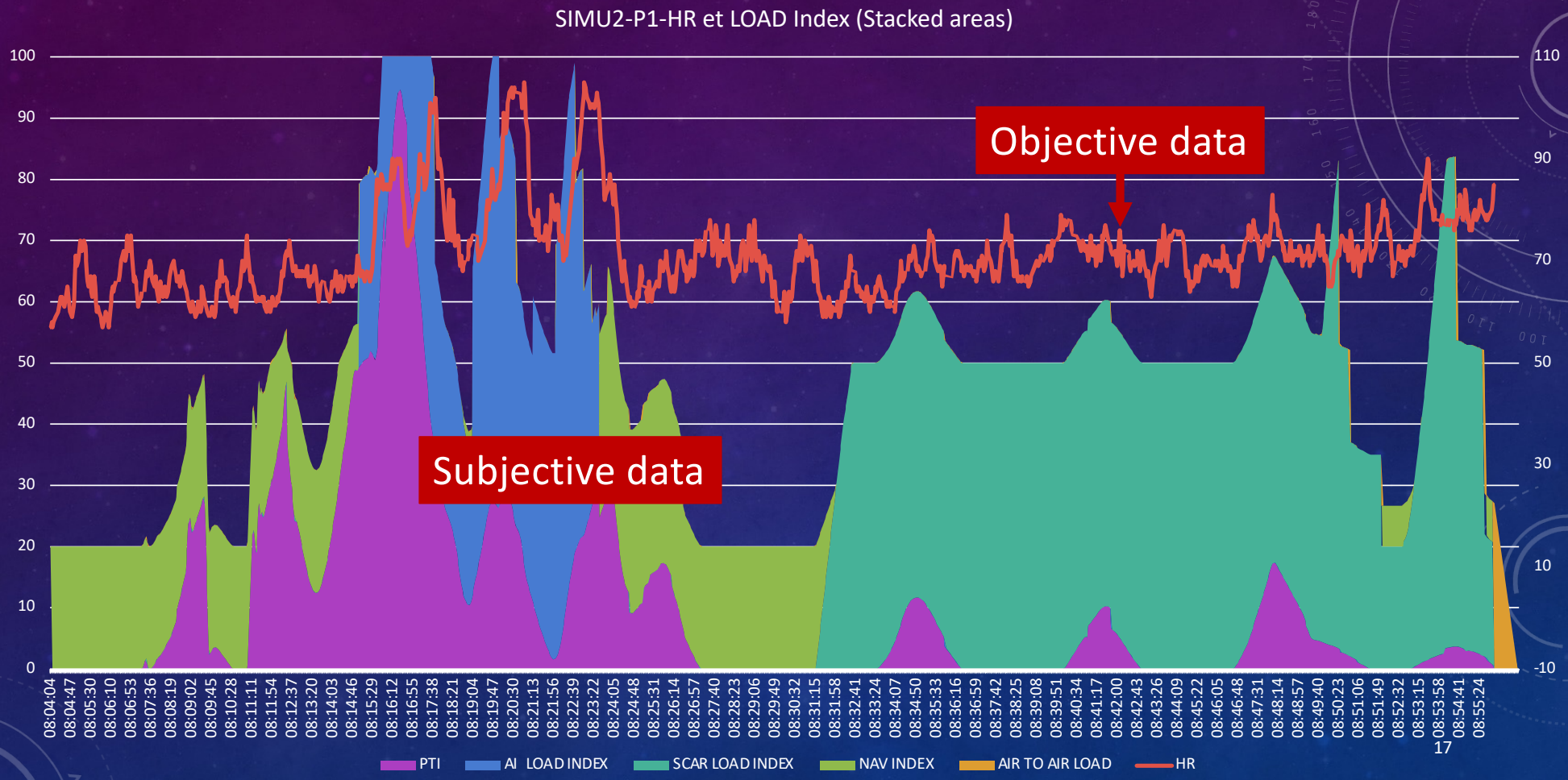






BPMN ACTIVITY ANALYSIS +

CORRELATION BETWEEN PILOT LOAD INDEX AND CFA RESULTS



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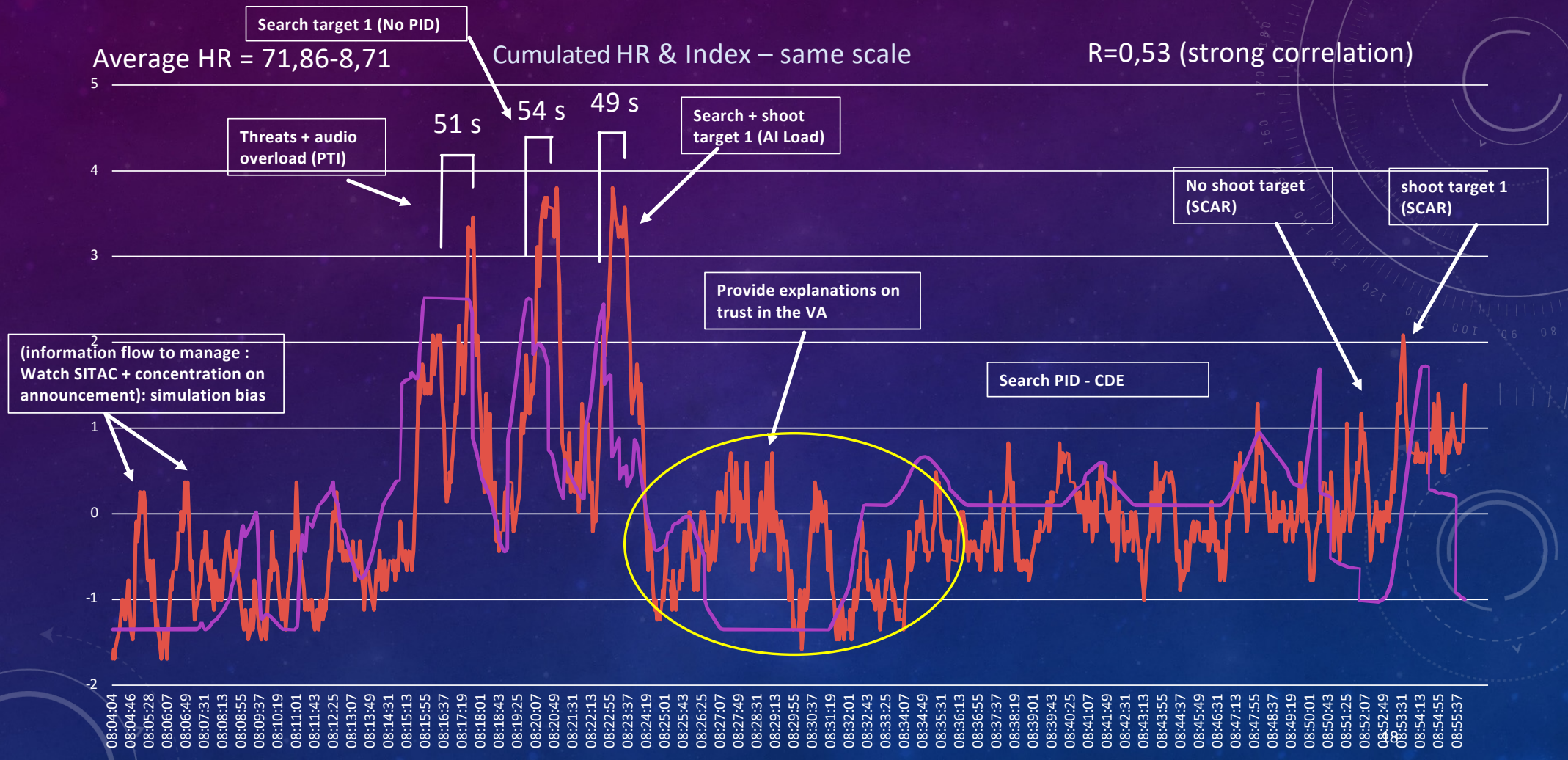


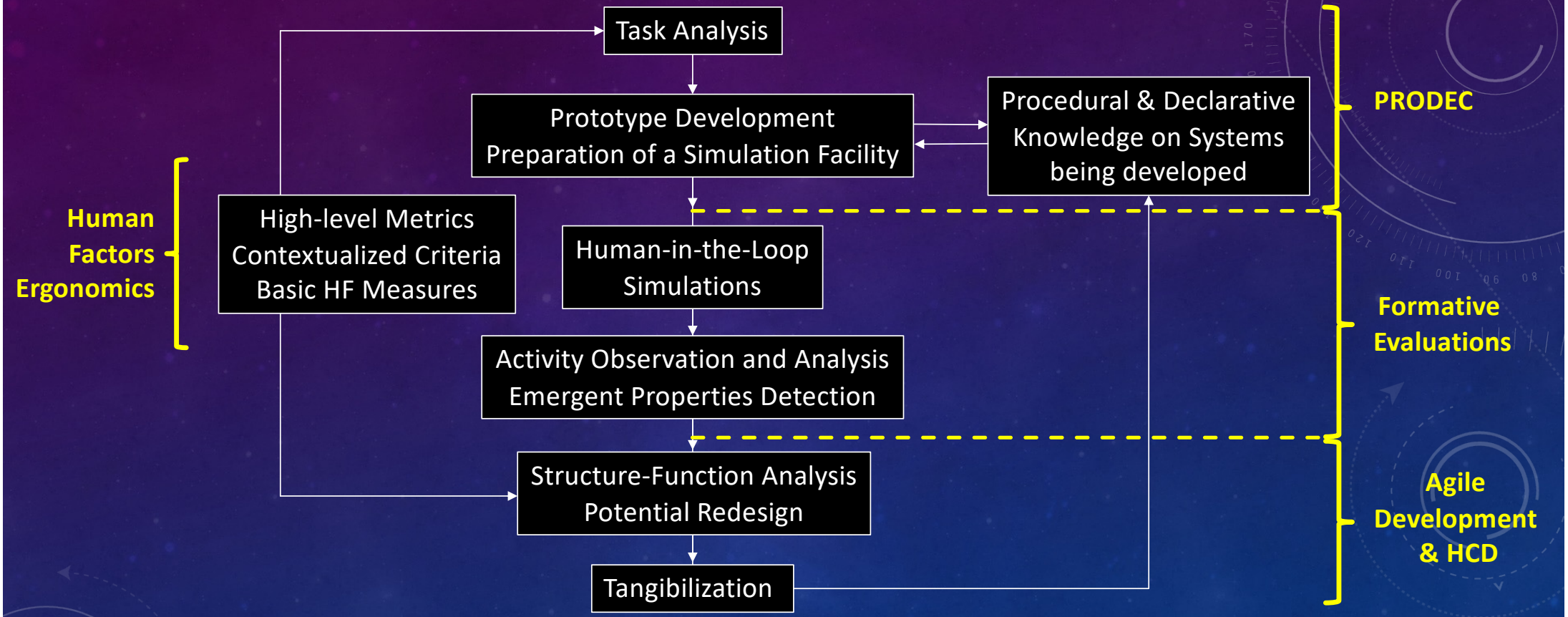
SUBJECTIVE LOAD INDICES VS. PHYSIOLOGICAL MEASURES

- Subjective load indices established by subject matter experts
- Physiological measures, such as heart rate
- Correlation between subjective and objective assessments
- Provides insight for trust or non trust
- Triggering more investigations…

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)

WORK IN PROGRESS (FCAS)

USE CASE 2 – OIL-&-GAS TELE-ROBOTICS
BASED ON PRODEC

A RESEARCH EFFORT SPONSORED BY TOTALENERGIES

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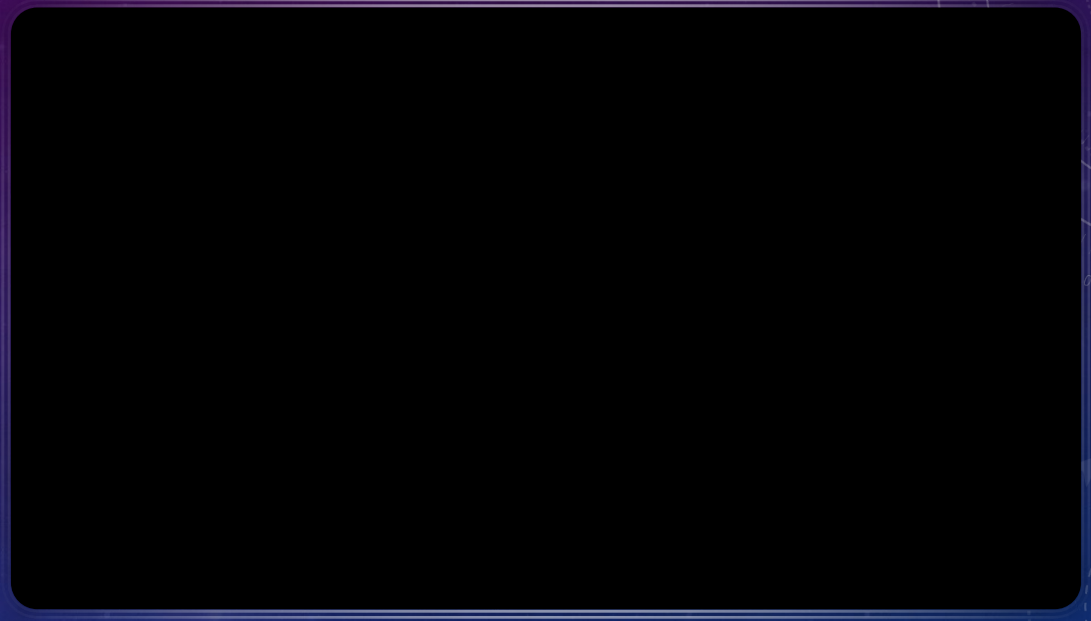
OFF-SHORE TELE-ROBOTICS PROOF OF CONCEPT

- Mobile robots replacing people
- Why? Safety and efficiency
- How? Using PRODEC

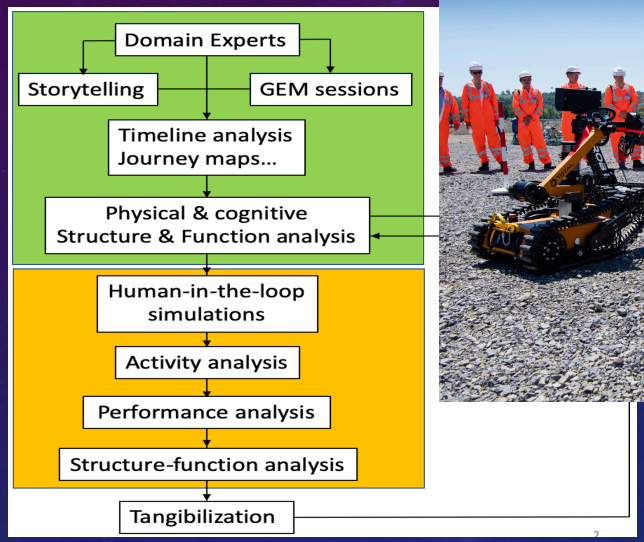


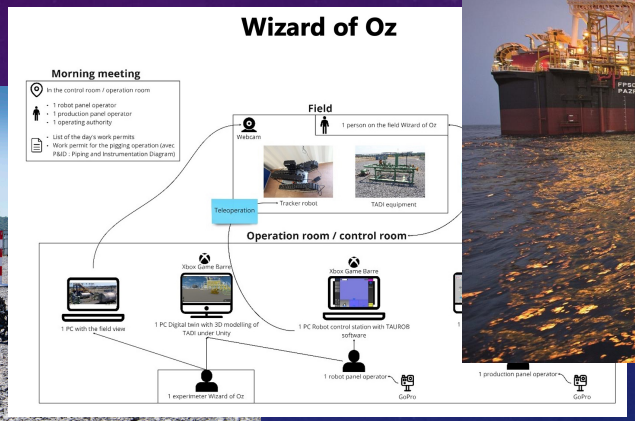
HSI OF AN OIL-&GAS TELE-ROBOTICS SYSTEM

- **Intensive use of PRODEC:**
  - **Combining PROcedural operations experience and DEClarative engineering methods**
  - **A Human-Centered Design (HCD) iterative approach**
- Elicit emergent systems' declarative knowledge from procedural scenarios
- Specification of a new operations room
- Identification of human operators' skills
  - Use case: pig launching ---------- →

OFF-SHORE OIL & GAS MULTI-AGENT TELEROBOTIC SYSTEMS

Using PRODEC method combined with HITLS

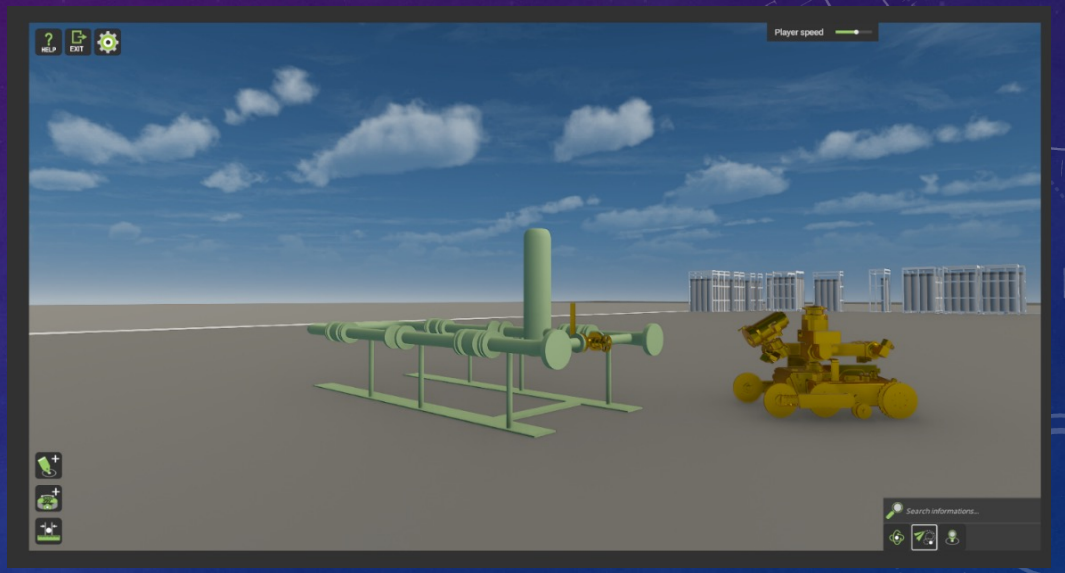




Tangibilization

PHYSICAL AND DIGITAL TWINS

Fake equipment simulating a pig launcher



Digital twin of the equipment and robot

USING PRODEC TO DESIGN AN OIL-&GAS TELE-ROBOTICS SYSTEM

- A Human-Centered Design (HCD) iterative approach
- Combining PROcedural operations experience…

  … and DEClarative engineering methods
- Using PRODEC to elicit **emergent** systems' declarative knowledge from procedural scenarios

Objectives

- Specification of a new **operations room**
- Identification of **human operators' skills** (use case: pig launching)

- AS-IS scenarios
- TO-BE scenarios

} **SBD**

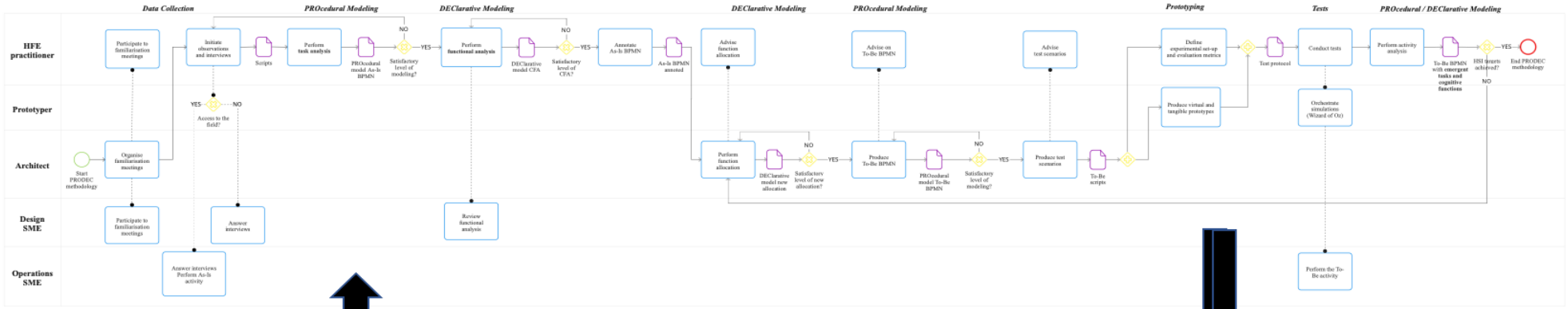
- Human-in-the-loop simulations

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

AS-IS MODELING

Objective: Describe the current process (as-is)

→ procedural task analysis and declarative structure/function analysis

1. **Familiarisation**
   - HFE practitioners need to be familiar with the Oil & Gas domain. They are not SMEs, but they must understand them.
   - Architects and SMEs must be made aware of the HFE methodology and terminology (PRODEC).
2. Choose representative **cases studies**
   - Calibration of gas detectors: a maintenance activity, with some handling and coordination with the control room.
   - **Pig launching:** a more complex activity involving numerous manipulations and coordination between agents.

3. Data collection

from SME to understand the current case study process, involving:

- Interviews
- Observations

Several experts are interviewed

- Gas detector calibration: a former OIM, a former maintenance operating authority, a former maintenance supervisor
- **Pig launching:** a former production operating authority, a production supervisor, an external operator

Information collected:

actors involved, tasks realized, necessary tools and resources, time and space information

AS-IS MODELING

4. Modelling in form of BPMN (Business Process Model and Notation),

cross validation with SME → **iteration**

PROcedural As-Is model BPMN:

multi-agents and multi-levels modelling *(cf Miro)*

5. Functional analysis, cross validation with SME → **iteration**

- Function are attributed to the different agents
- Ontological approach to generalize functions
- Categorization according to :
  - Situation awareness level (Endsley, 1995): Situation Awareness (SA), Decision Making (DM), Action Taking (AT)
  - Rasmussen levels of functions (Rasmussen, 1983) : Skills based (S), Rules based (R), Knowledge based (K)

Function	Definition	Type	Cognitive resources
Go	Move around	AT ; S	Execution
Apply	Follow procedures or rules	AT ; S	Execution
Approve	Give approval (to sth.), because one has the competence and authority to do so	DM ; K	Selection
Check	Examine, look for information	SA ; R	Perception Comprehension
Document	Carry a certain amount of information on a support	AT ; S	Execution
Listen	Pay attention to what someone is saying in order to hear and understand it	SA ; R	Perception Comprehension
Equip	Provide themselves with the necessary equipment for a given activity	AT ; S	Execution
Inform	Transmit, communicate information	AT ; S	Execution
Insert	Enter information into a system	AT ; S	Execution
Inspect	Observe carefully and thoroughly the good condition or functioning of, to check and verify	SA ; K	Perception Comprehension Projection
Manipulate	Handle sth. in view of an operation	AT ; S/R	Execution
Validate	Confirm, make or declare valid	DM ; K	Selection
Verify	Ensure compliance of parameters	SA ; R	Perception Comprehension Projection

TO-BE MODELING

Objective: Imagine scenarios of future operations (to be)

1. **Function allocation**, between the agents according to their abilities, experience, work environment, difficulty of the task, and the resources needed to perform it, cross validation with architect → **iteration**

- Based on the type of function and the cognitive resources that the function requires *(table)*
  - **Verification and inspection task are kept on human**
  - Listening and informing become receiving and sending information

External operator functions	Allocation
Go	Robot
Apply	Robot
Listen	Robot → Receive
Equip	Robot
Inform	Robot → Send
Insert	Robot
Inspect	**Human**
Manipulate	Robot
Verify	**Human**

TO-BE MODELING

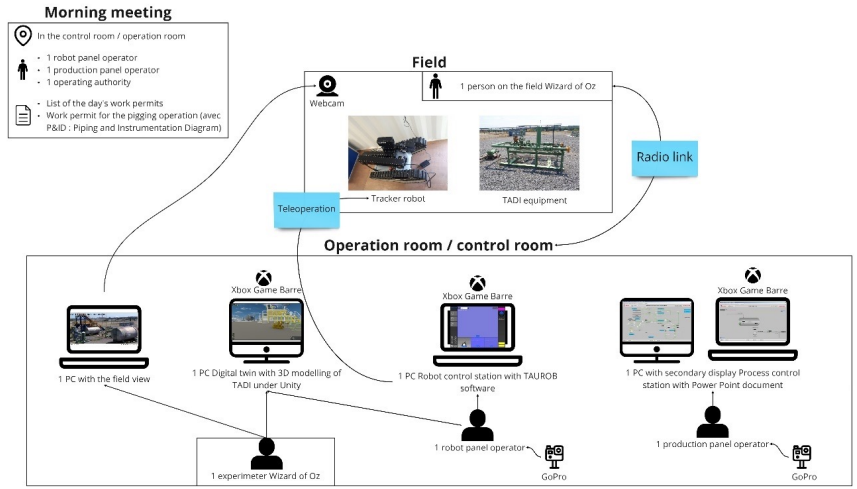
2. BPMN modelling, proposition of different scenarios with different degrees of automation, different situations (normal, abnormal and emergency), cross validation with architect → **iteration**

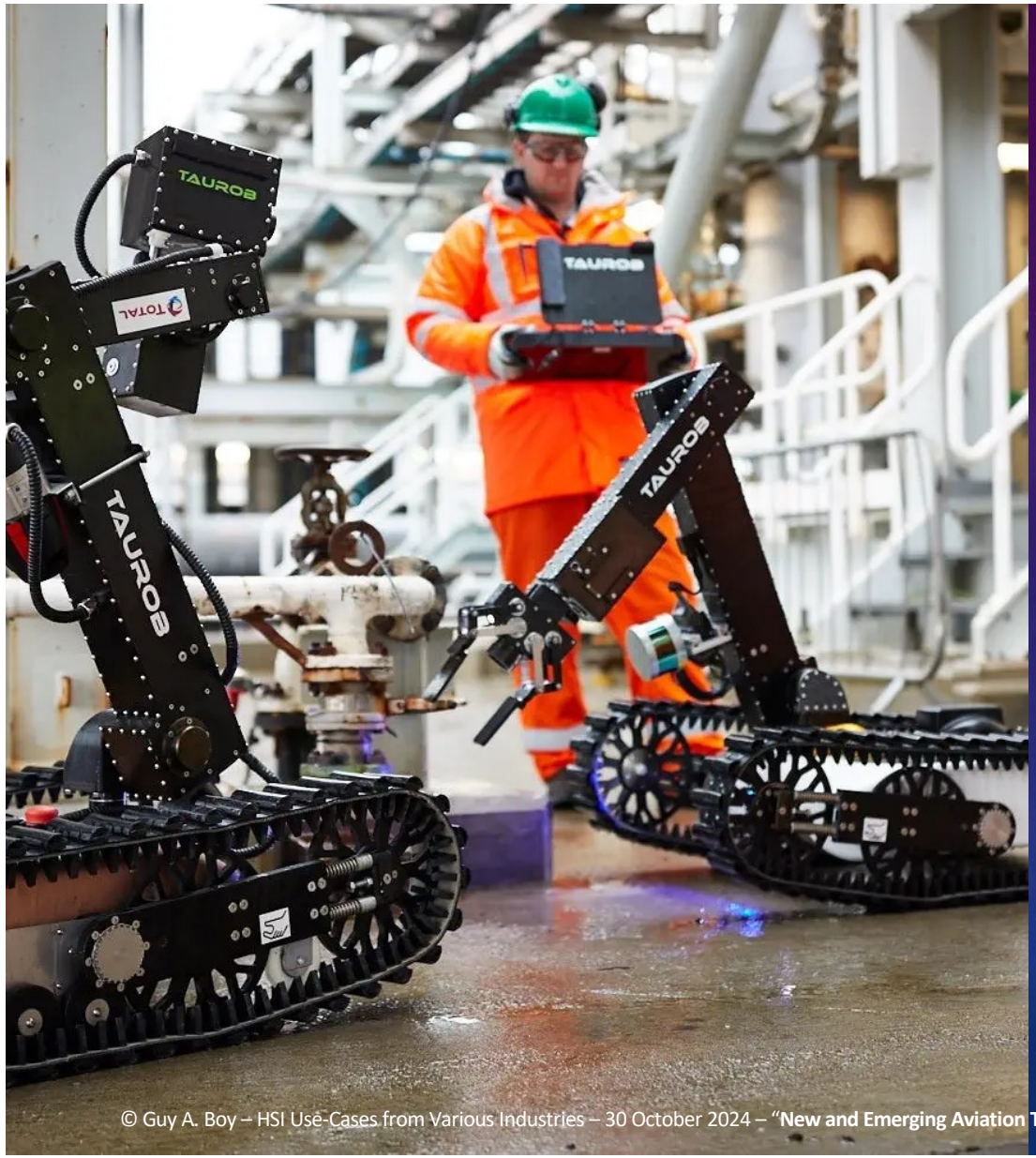
- **PROcedural To-Be model BPMN:** *(cf Miro)*
  - Predicted functional capabilities of the robots
    - We can predict from the analysis some capabilities (carrying, identifying valves, etc.)
  - Prescribed organization of the Oil & Gas facilities:
    - Separation control room (process) / operation room (robot fleet)
  - **Iterative process involving experts and creative sessions**
  - Several concurrent scenarios have been proposed and discussed for the simulations

External operator functions	Allocation
Go	Robot
Apply	Robot
Listen	Robot → Receive
Equip	Robot
Inform	Robot → Send
Insert	Robot
Inspect	**Human**
Manipulate	Robot
Verify	**Human**

HUMANS-IN-THE-LOOP SIMULATIONS

TANGIBILIZATION OFTEN REQUIRES MAGIC TRICKS





HUMAN-IN-THE-LOOP SIMULATIONS

- **Objective:** study the behaviour of users in front of a system in a context of use, in order to detect its strong points, its weak points and the points to improve. To test the system in a context of use, test scenarios must be created before the simulation

- Several rounds of human-robot testing with different scenarios of increasing difficulty (normal, anormal and emergency situations)

ADVANTAGES OF PRODEC

- Recognized in the oil-and-gas sector
- Enables preserving the purpose of the operations
- Enables functions re-allocation (AS-IS → TO-BE)
- Very useful for training purposes, especially considering emerging situations

WORK IN PROGRESS (DEVELOPMENT)

USE CASE 3 – REMOTE MAINTENANCE OF HELICOPTER ENGINES

A RESEARCH EFFORT SPONSORED BY SAFRAN

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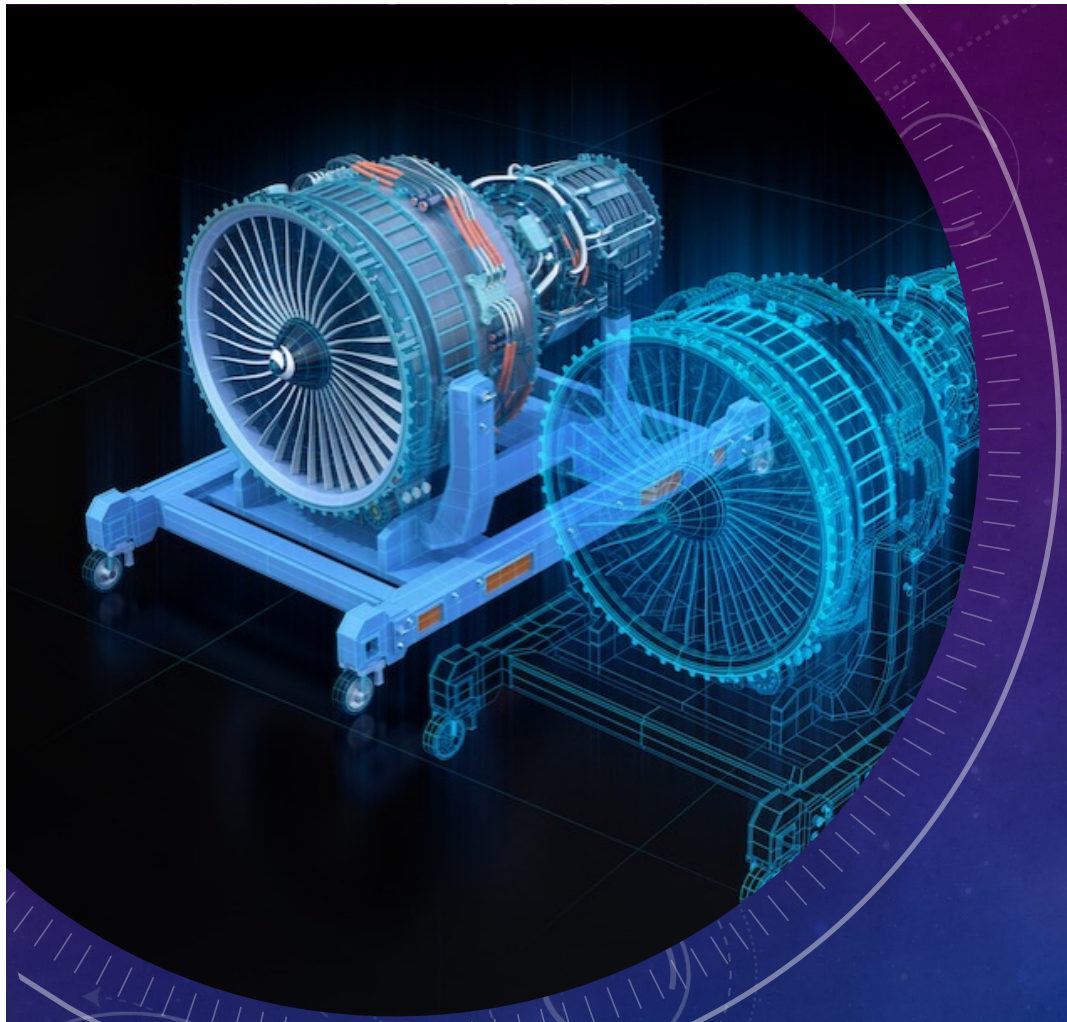
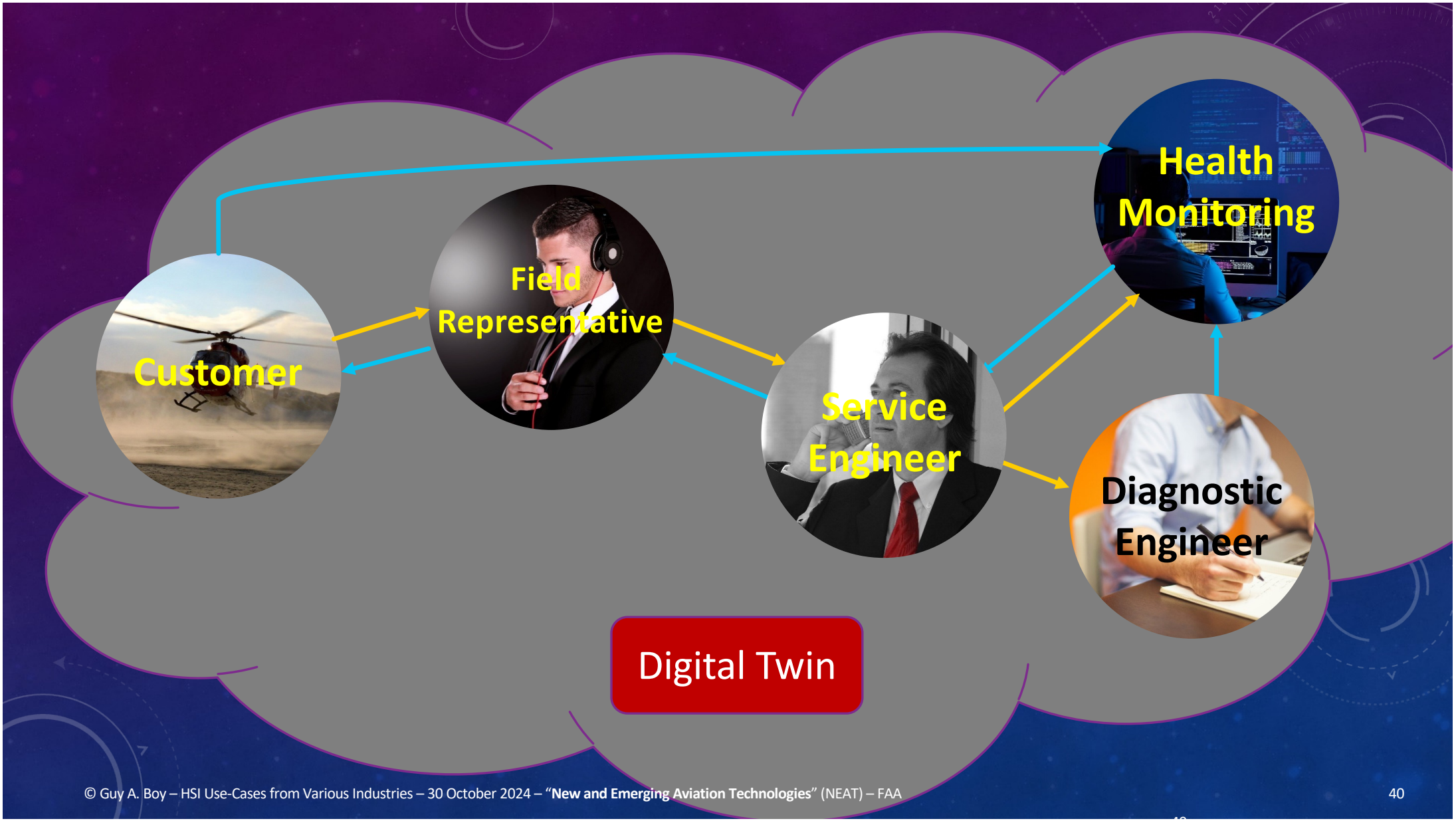


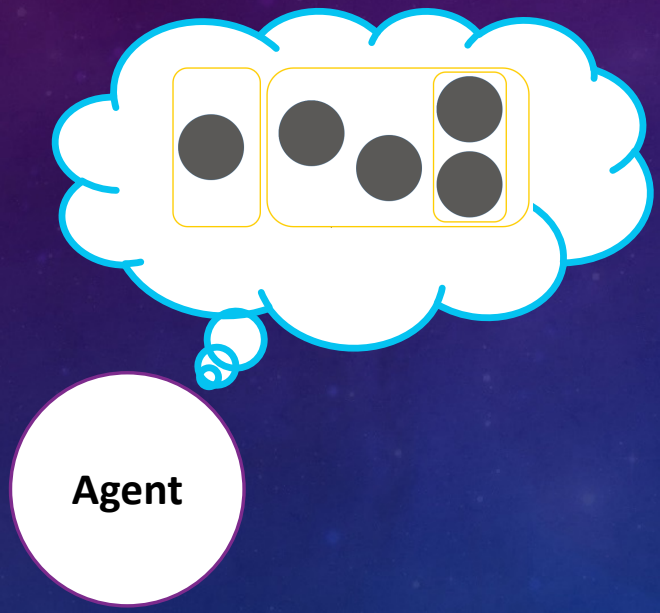
HELICOPTER ENGINE MAINTENANCE PROBLEM…


Health Monitoring
Field Representative
Customer
Service Engineer
Diagnostic Engineer
Digital Twin

MULTI-AGENT DIGITAL TWIN

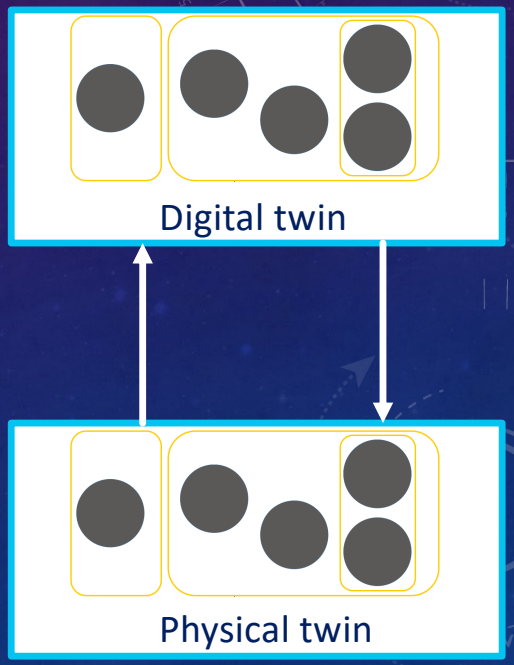
Situation awareness

"Perception of the elements of an environment in a volume of time and space, understanding of their meaning and projection of their state into the near future."
(Endsley, 1995)

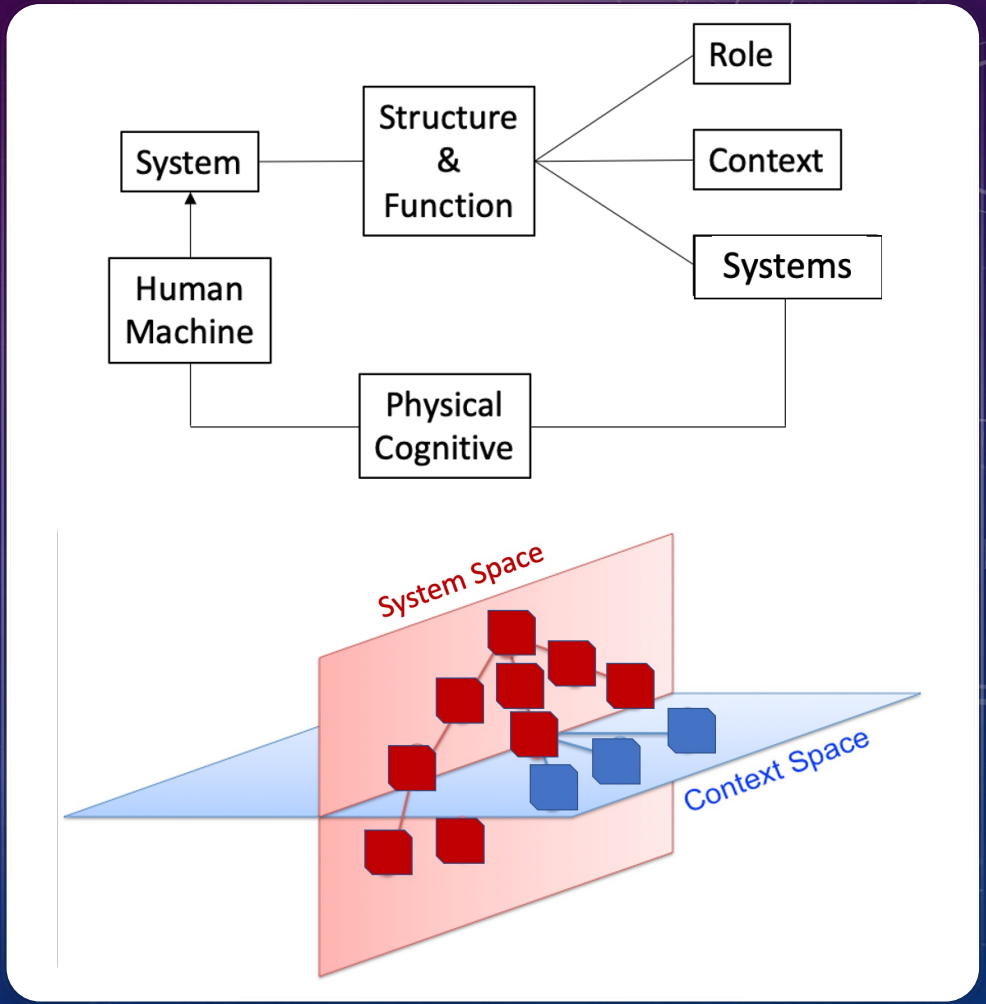


Digital twin

"A dynamic representation of a physical system using data, models and interconnected processes to enable access to knowledge of past, present and future states to manage action on this system"
(Camara Dit Pinto et al., 2021)

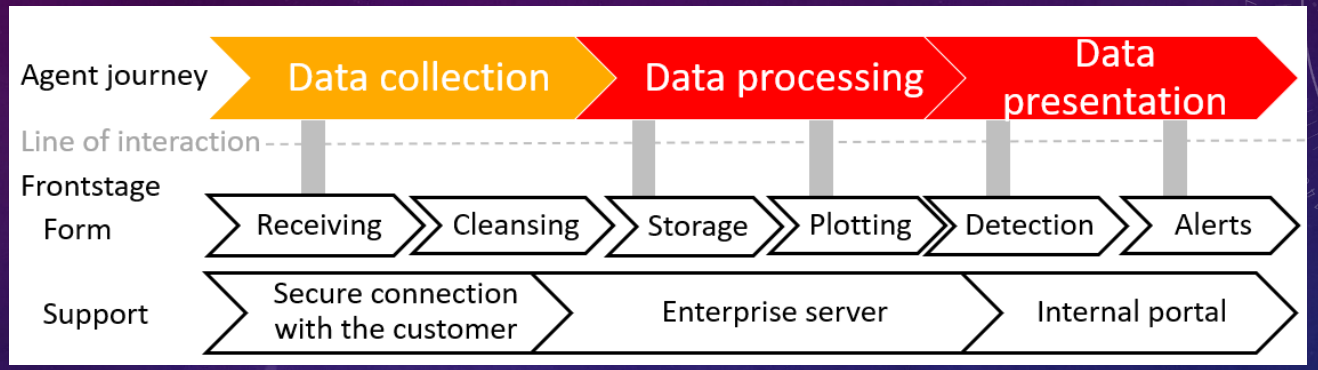


AGENTS AS SYSTEMS

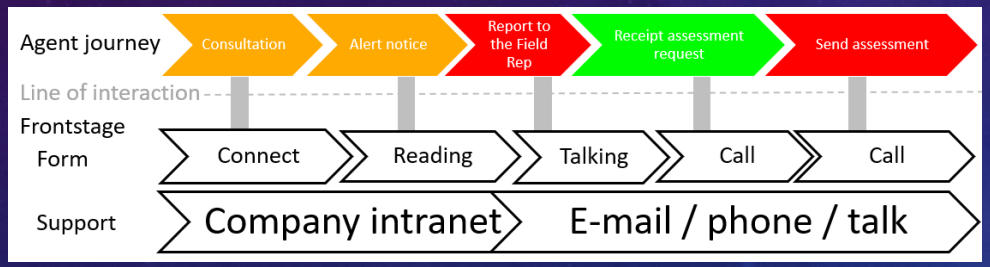


FIELD STUDY

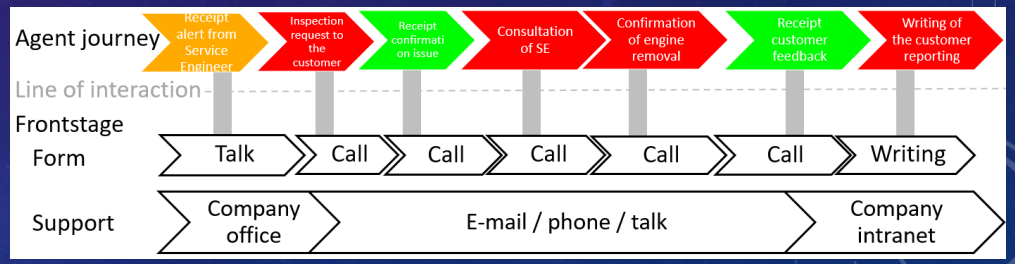
Health Monitoring



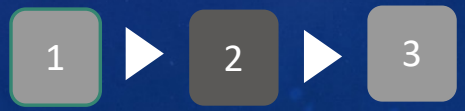
Service Engineer



Field Representative



Action Observation Reward



MULTI-AGENT PRODEC

- Development of a digital twin
- Human-in-the-loop simulations
- Activity observation & analysis
- Incremental agile re-design of the digital twin

AI4SE & SE4AI…

WORK IN PROGRESS (RESEARCH EFFORT)

QUENTIN LORENTE, PH.D. STUDENT

USE CASE 4 – REMOTE AND VIRTUAL AIR TRAFFIC CONTROL CENTER

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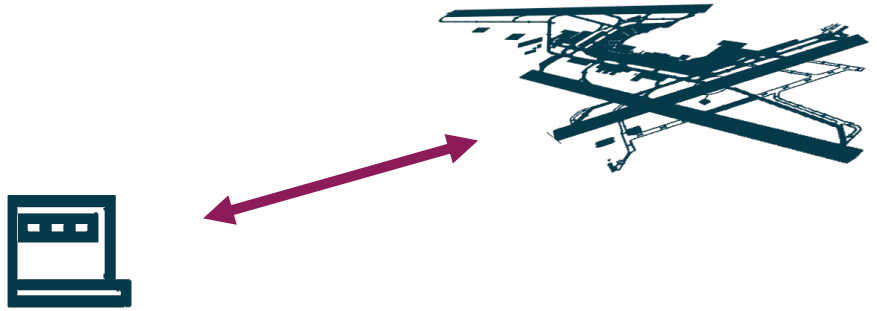
WHAT WE MEAN BY REMOTE AND VIRTUAL TOWERS (RVT)

What exists

Traditional air traffic control tower

What we want



Remote air traffic control center

RVT ADVANTAGES

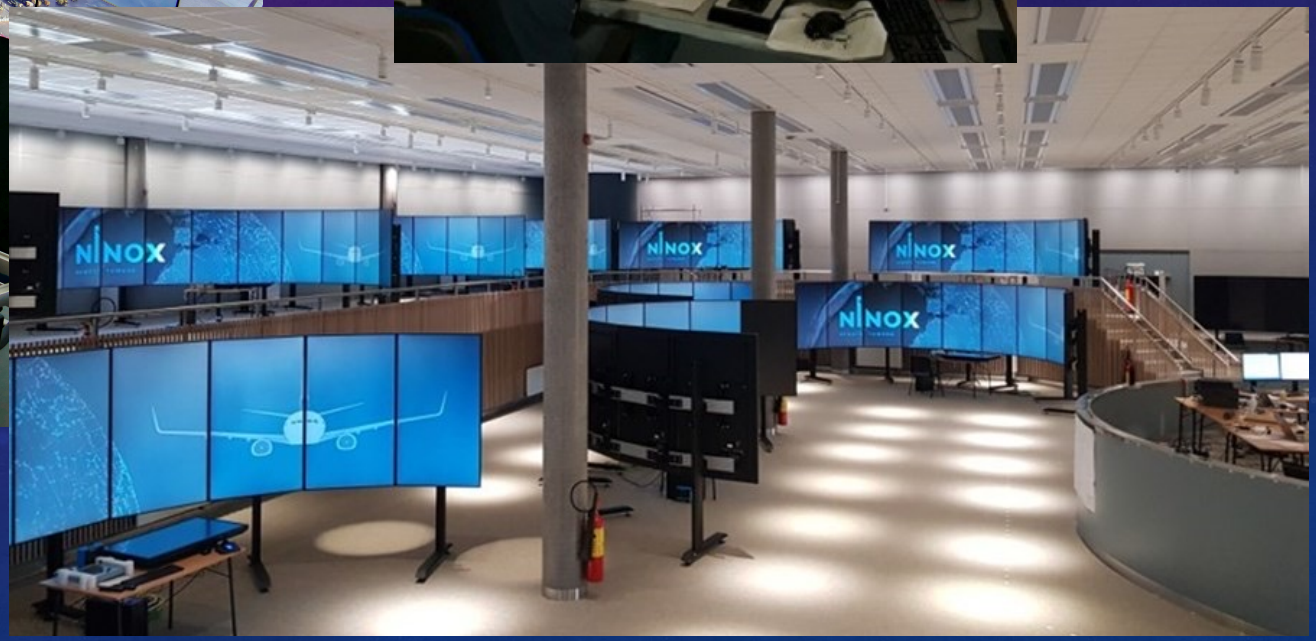
Objectives

- **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

OPERATIONAL READINESS OF RVT TODAY

NATS

ENAV



Avinor

FROM REMOTE 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 a virtual center as a complex sociotechnical system, following an HSI approach…

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**

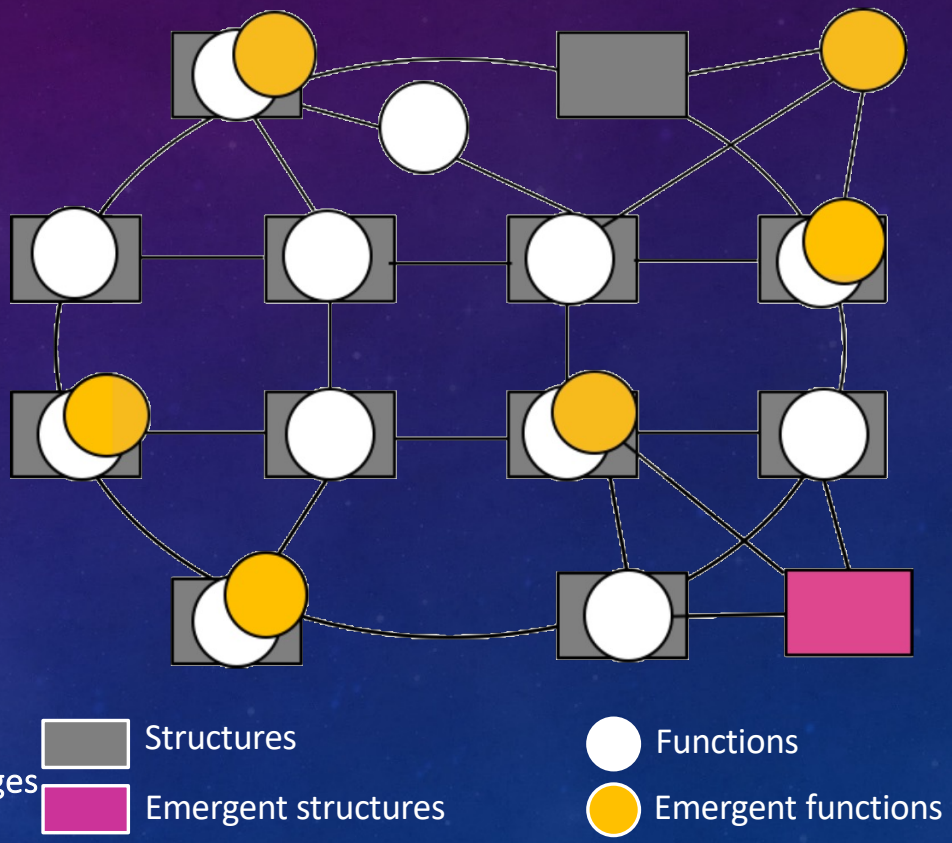
  So activity cannot be observed at design time

  Hence emergent properties cannot be detected early!

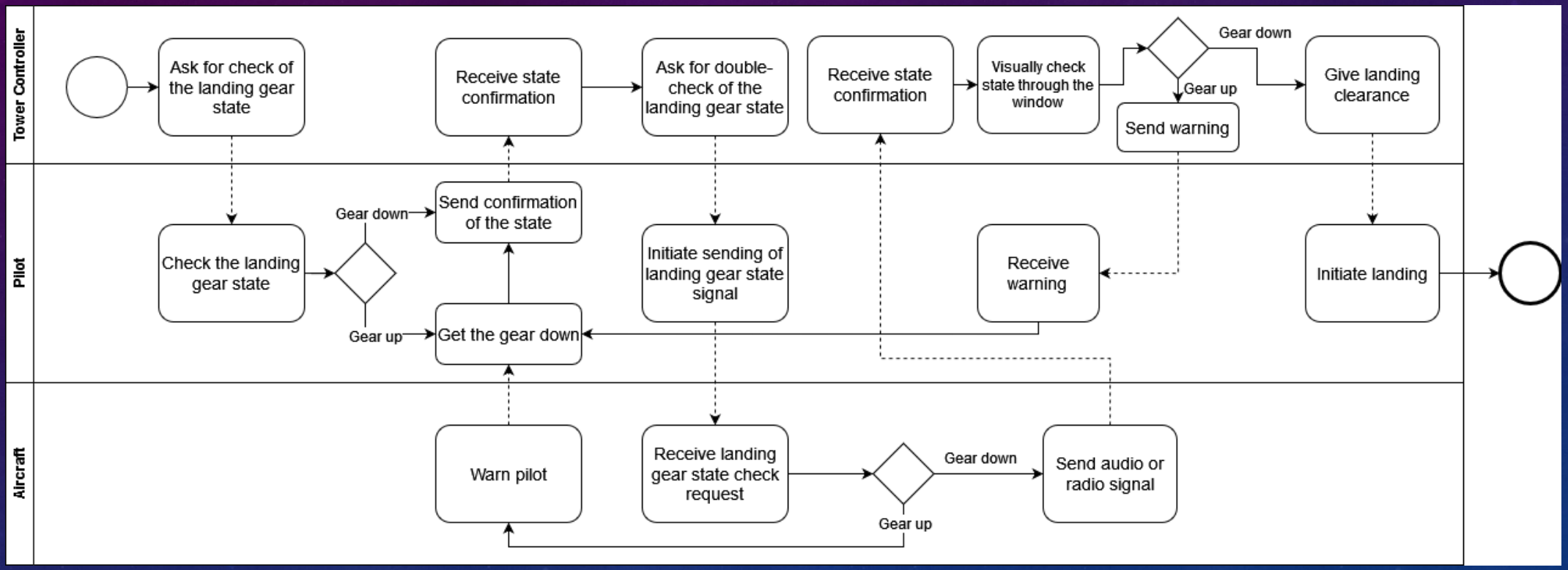
- **New solution: human-in-the-loop simulation**

  Enables virtual human-centered design (HCD)

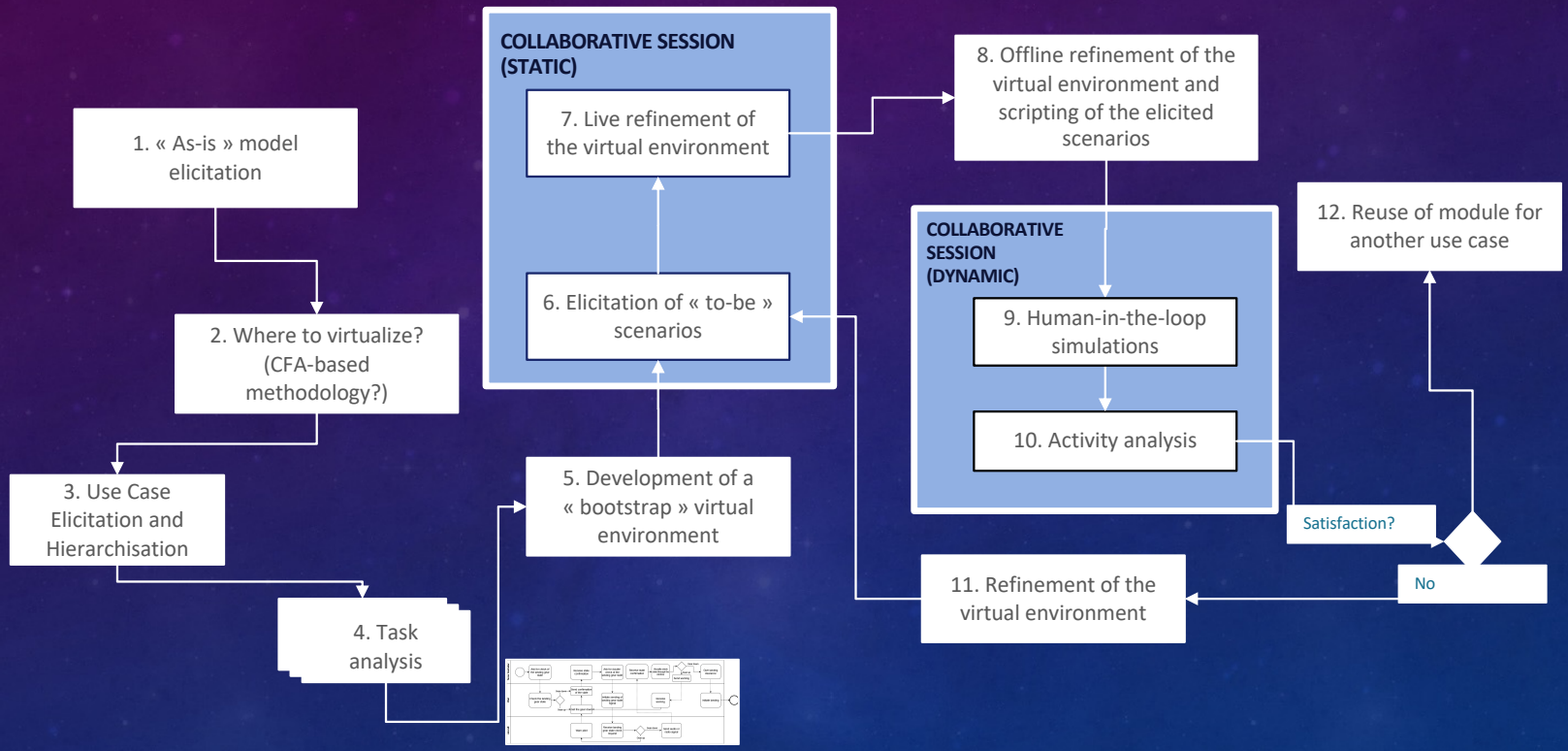
  Support observation of human activity during early design stages



AN HITLS EXAMPLE FOR AIR TRAFFIC CONTROL VIRTUALIZATION



OVERVIEW OF THE PROCESS



WORK IN PROGRESS (RESEARCH EFFORT)

ALEXANDRE DISDIER, PH.D. STUDENT

OTHER ONGOING HSI PROJECTS…

INNOMED

FCAS

MB-HSI of highly automated trains

FlexTech

CentraleSupélec–ESTIA Chair

FlexTech

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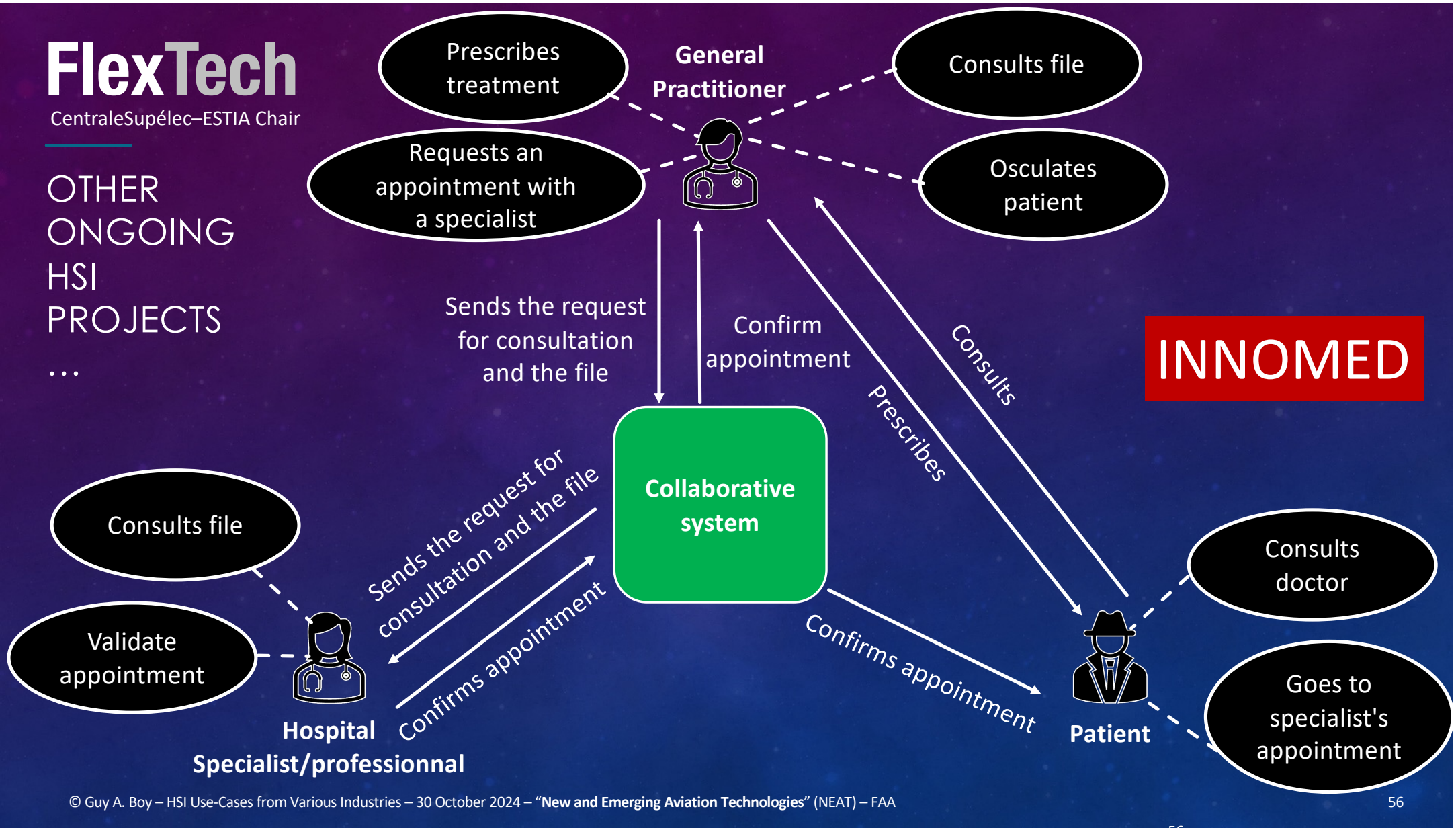
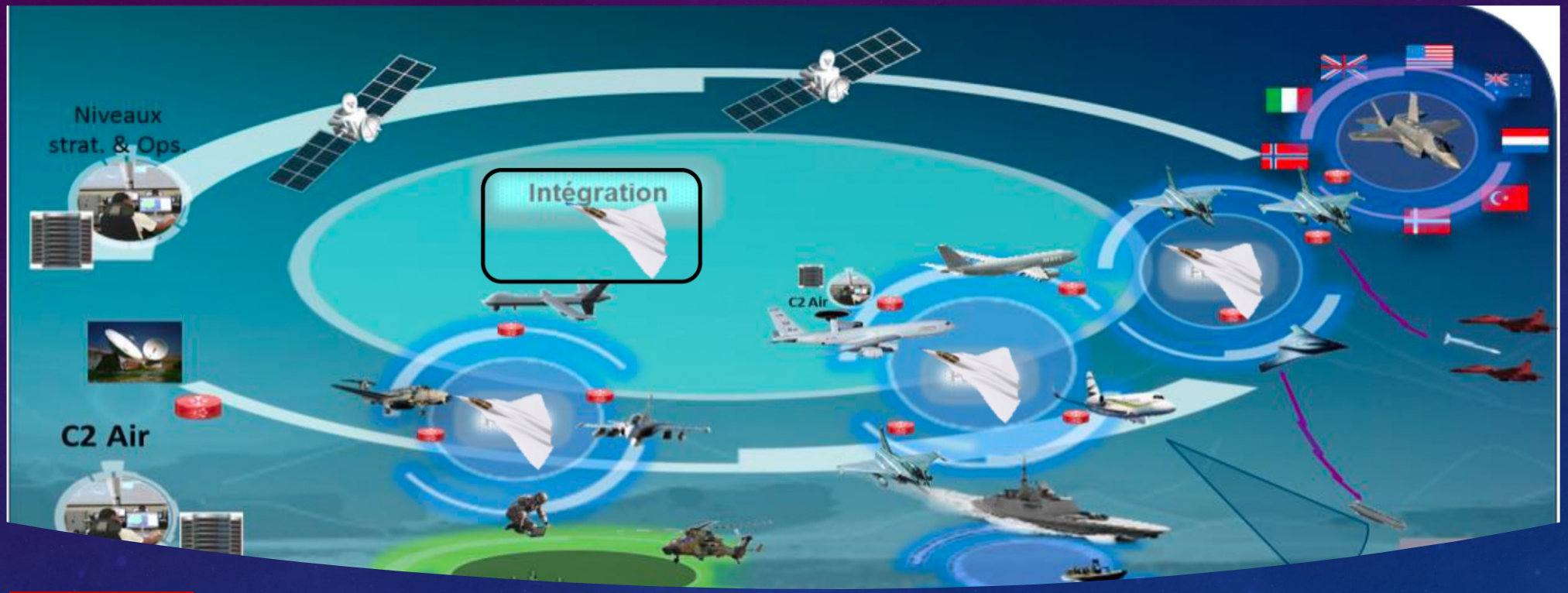
OTHER ONGOING HSI PROJECTS …



OTHER ONGOING HSI PROJECTS…



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OTHER ONGOING HSI PROJECTS…

MB-HSI of highly automated trains

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THANK YOU…

… DISCUSSION