USE CASE : AIR COMBAT SYSTEM
MOHICAN PROJECT

HAT Spring School 2024

Chloé MOREL and Laurent GOUMY

MMT Man Machine Teaming Program

What is MMT program ?

- **The Man Machine Teaming (MMT) project aims to prepare the artificial intelligence technologies needed for the combat aviation of the future. It was officially launched on March 16, 2018**
- **MMT is an initiative financed by the French Industry of Defense (DGA) and managed by Thales and Dassault Aviation.**
- **The aim is to create an industrial ecosystem that will enable innovations to be detected, evaluated, and, ultimately, matured and integrated into the development of future combat aircraft.**
- **TRL (Technology Readiness Level) 4**

MOHICAN Project objectives

Propose a method for evaluating the performance of the team composed of a pilot and a virtual assistant (VA) in the cockpit of a simulated combat aircraft, using trust and collaboration models and metrics

- Create a trust and collaboration model
- Propose trust and collaboration metrics based on tangible virtual prototypes
- Consider the operational context for the analysis of trust and collaboration.
- Develop the VA system
- Perform human-in-the-loop simulations

The partner: Synapse Défense

Collaborative Training
Coaching

Mission preparation

Creation of high intensity scenario
Mission tactical planning coaching

Mission execution

Supervision & mission animation
Replication of missing assets
Live shots assessment
Framing and conduct of adversity

Post Mission

Data collecting
Mission debrief and lessons identification
Performance analysis

Air Operations Modeling & TACTICAL STUDIES

LEVERAGE WORK EXPERIENCE TO SUPPORT THOSE WHO NEED IT …

SYNAPSE DÉFENSE

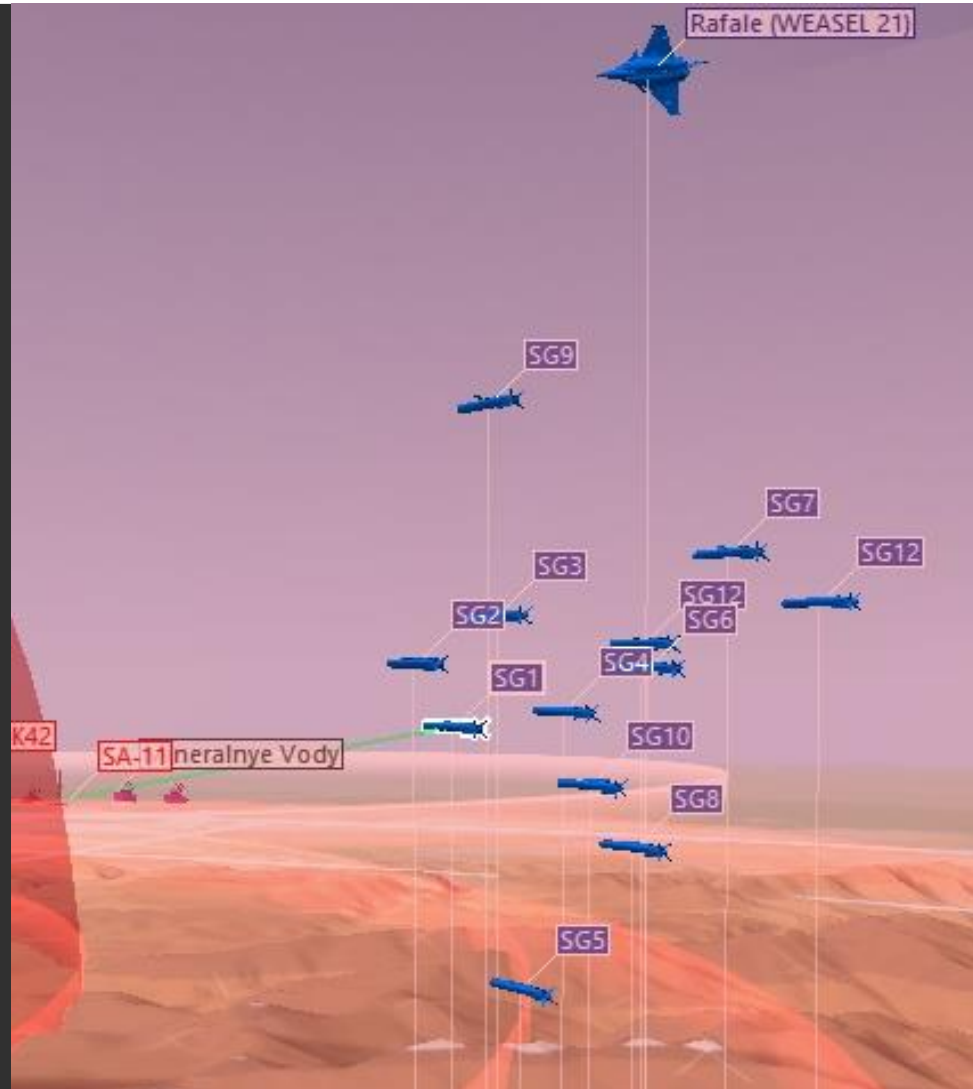
TACTICAL STUDIES AND CONSULTING

Operational support: Study scenario construction, operational requirements identification, development assistance, testing & analysis

AIR OPERATIONS MODELING

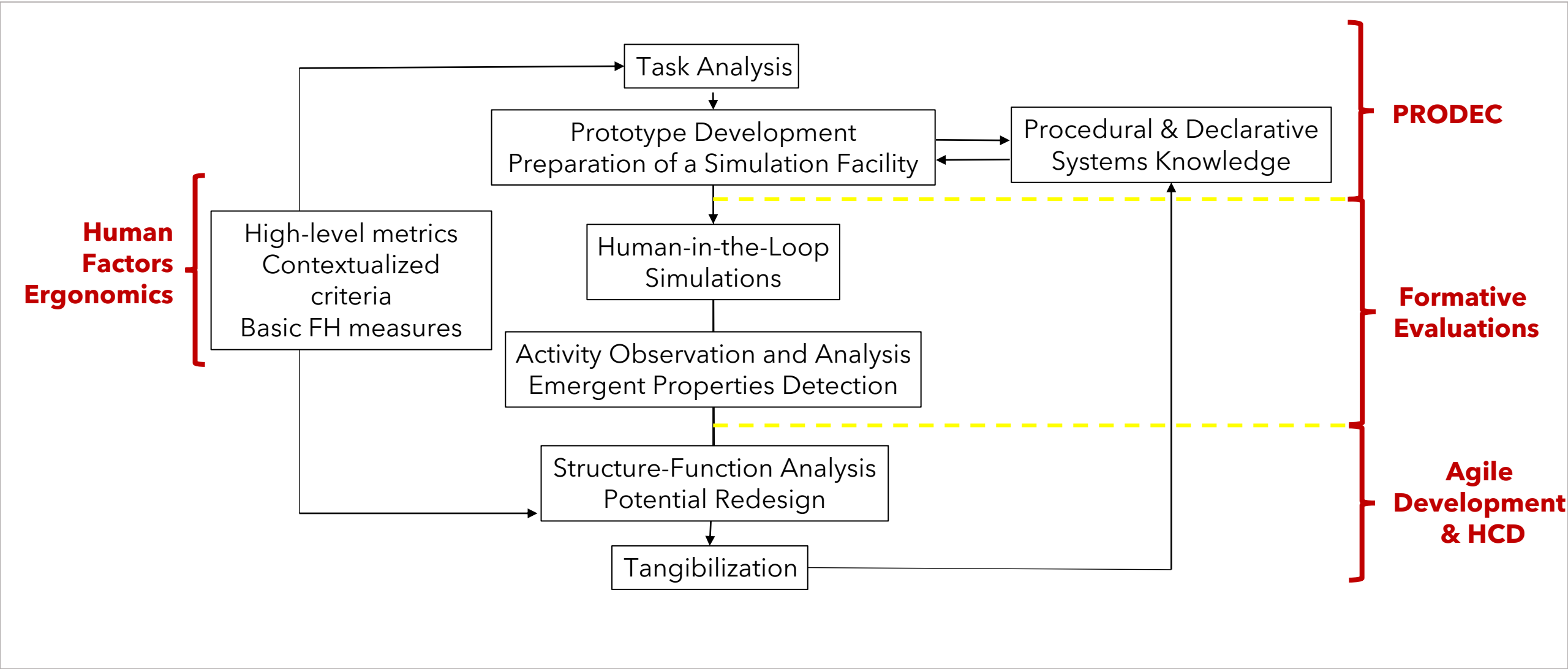
Creation & animation of a modular Simulation environment dedicated to collaborative operations, designed for:

- Artificial Intelligence learning,
- Relevant technical orientations identification
- COLLABORATIVE COMBAT CONCEPT VALIDATION, AND SUBSEQUENT SPECIFICATIONS WRITING



PRODEC methodology

Scenario-based design procedure



PRODEC method

- **PRODEC is based on the HCD (Human-Centered Design) approach, combining PROcedural experience of operations and DEClarative engineering methods.**
- The role of PRODEC is to support the systematic emergence of declarative knowledge about systems from procedural scenarios.
- PRODEC is based on scenarios :
  - As-Is scenarios and To-Be scenarios
  - Human-in-the-loop (HITL) simulations

=> PRODEC must be used iteratively

As-Is modelling

Objective: Describe the current process (as-is) : produce a procedural analysis of tasks and a declarative analysis of structures and functions.

Step 1- Choose representative cases studies

Step 2 - Data collection from expert to understand the current case study process, involving:

- Interviews,
- Observations,

⇒ Info collected: actors involved, tasks realized, tools and resources necessary, temporal and spatial information.

⇒ Several experts are interviewed

As-Is modelling

Step 3 - Modelling in the form of BPMN (Business Process Model and Notation), cross - validation with expert → **iteration.**

- multi-agents and multi-level modeling
- Ingescape Circle

Step 4 - Functional analysis, cross - validation with expert → **iteration**

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

Fonctions	Definition	Type	Cognitives ressources
Act	Operate aircraft functions using tangible buttons	AT ; S	Motor fonction, proprioception/validation by pilot
Communicate	Transmit information to partners	AT ; R	Perception/validation by pilot
			Attention/Timing (reaction to stimuli)
			Memory; learning/thinking aloud
Understand	Analyze a situation and its impact on the mission	SA ; R	Memory/enumeration
			Reasoning/explanation
Decide	Making a decision	DM ; K	Memory/enumeration
			Decision making/decision tree
Listen	Pay attention to what someone is saying in order to hear and understand it	SA ; R	Perception/validation by pilot
			Attention/Timing (reaction to stimuli)
			Mémoire énumération sur rejeu
Perceive	Consciously assimilate a range of information	SA ; S	Perception/validation by pilot
			Memory; learning/thinking aloud
			Temporal reasoning/measurement (speed of inference)
Fly	Drive the aircraft and place it on a suitable trajectory	AT ; S	Memory; learning/thinking aloud

To-Be modelling

Objective: Imagine scenarios of future operations (to be)

Step 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 function type and required cognitive resources

Step 2 - BPMN modelling, creation of scenarios with different degrees of automation, different situations (e.i. normal, abnormal and emergency), cross-validation with an HSI architect → iteration

- Several concurrent scenarios are proposed and discussed for the simulations

Human-in-the-loop

Objective: study the behavior of users in front of a system in a context of use, to detect its strong/weak points, the points to improve and emergent functions.

- Several rounds of human-system testing with different scenarios of increasing difficulty (normal, abnormal and emergency situations).

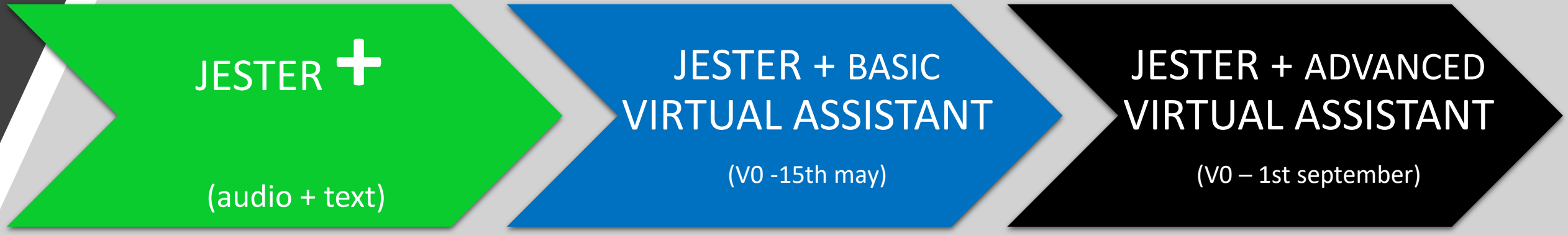
MOHICAN Project

Simulation

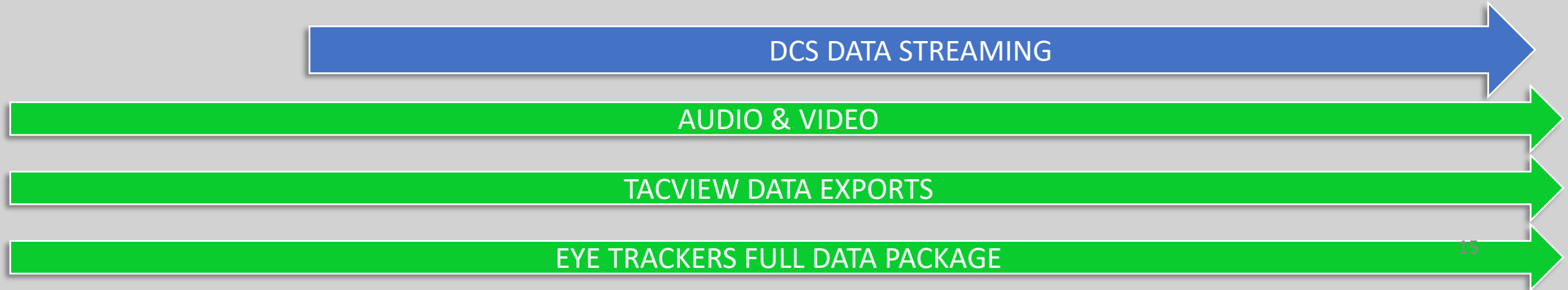
	SIMU1	SIMU2	SIMU3	SIMU4	SIMU5
VA	Jester +	Jester BASIC	JESTER BASIC	Jester ADVANCED	Jester ADVANCED
Complexity	+	+	++	++	+++

Virtual Assistant

Virtual Assistant improvements to enhance Trust & Collaboration



Data Collecting to increase basic measures availability for HMT KPIs



Tools and metrics

- Eye tracking glasses (Tobii): Activity analysis
- The Observer XT (Noldus): Video encoding
- Hear rate sensor
- Standardized scales: SUS, NASA-TLX, SART, Scale of trust in Automated Systems.
- Performance mission metrics based on expert evaluation
- Evaluation grid: analysis of trust and collaboration criteria (questionnaires, post-simulation interviews, objectives data)
- Pilot cognitive engagement index (or Pilot Load Index) (Synapse algorithm): measures available context/situation with the help of Heart rate monitor

Focus : Evaluation grid

Objectives :

- qualify the level of trust and collaboration for each interaction;
- Improve VA through an HCD approach.

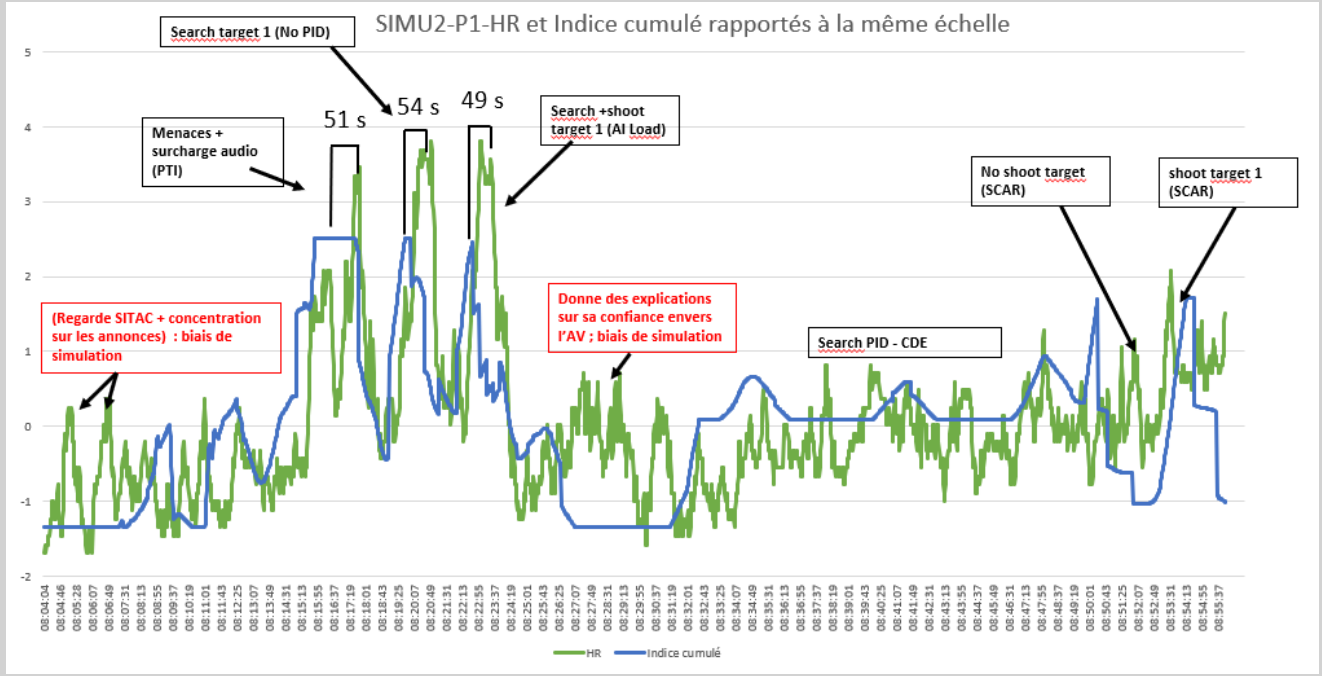
Selection of evaluation criteria from the literature :

- Meaning, explicitness and terminology (ontology)
- Measurability (objective versus subjective measurements)
- Use case relevance
- Influences over time

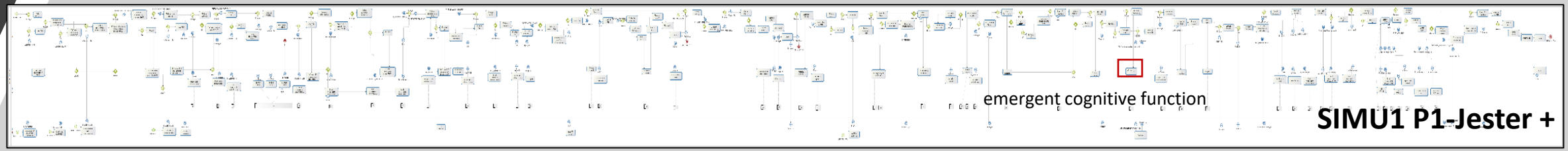
=> List of 9 criteria for analyzing the quality of each interaction: Effectiveness - Efficiency - Reliability/robustness - Relevance - Transparency - Flexibility/adaptability - Quality of feedback - Perceived lightening of the task - Absence of discomfort.

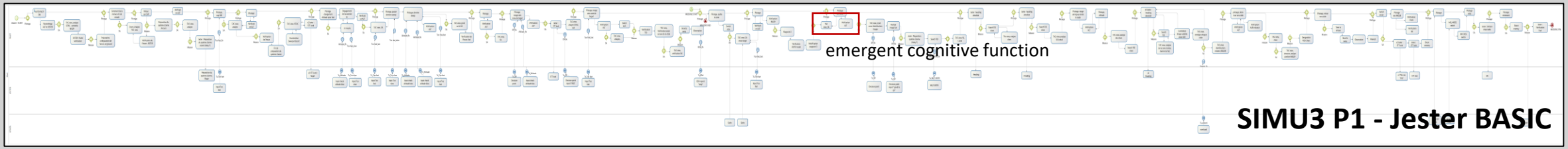
Focus : PILOT COGNITIVE ENGAGEMENT INDEX

- Creation of an algorithm to model risk management based on objective data such as flight data (e.i. too slow, too fast), Navigation data (e.i. fuel compliance), context (threat distance) etc...
- correlation with heart rate measurements very promising.



Review





	Expérimentateur (objectif) : qualité de l'interaction					Pilote (subjectif) : perception de l'interaction						
	Efficacité		Efficience	Fiabilité/robustesse		Pertinence	Transparence		Flexibilité/adaptabilité	Qualité du feedback	llègement perç	Gêne
Index cumulé	Information traitée (feedback) (eye tracking, actions du pilote ou verbalisation du pilote) (OUI/NON)	Vérification de l'information (double check) (OUI immédiatement/OUI ultérieurement/NON)	Temps total de l'interaction (temps de réaction, manipulation de l'interaction) (en sec)	bug (OUI/NON+description)	Default fonctionnel (OUI/NON+description)	valeur ajoutée (A décrire : allègement de la tâche, amélioration de la performance/sécurité, amélioration de la connaissance de la SA, etc...) (OUI/NON)	perception de l'information (OUI/NON+description)	interprétation/compréhension de l'information (OUI/NON+description)	Adaptabilité au pilote ou au contexte (OUI/NON+description)	Qualité du feedback (Note de 0 à 10, 0 = pas de feedback)	Allègement perçu de la tâche (OUI/NON+description)	Absence de gêne (OUI/NON+description)
/	OUI (action sur le throttle)	OUI (? x eye tracker)	Temps de réaction < 3 sec donnée altitude : 24,3 kft -> 4 sec pour revenir dans le bloc (24,5 kft)	OUI ecart de calage altimétrique non identifié par le pilote	NON	OUI	OUI	OUI	OUI (information transmise lorsque le pilote gêne sa navigation)	OK	Moyenne le pilote réalise plusieurs vérifications	NON vérifications successives de l'ALT
20	NON incompréhension du pilote	OUI immédiatement (eye tracking)	(1-3s) Perte de temps lié à la vérification de l'ALT	ecart de calage altimétrique	NON	NON surcharge d'information audio	OUI	NON incompréhension	NON le pilote a déjà traité l'information	OK	NON	NON
20	NON incompréhension du pilote	OUI immédiatement (eye tracking)		ecart de calage altimétrique	NON	NON surcharge d'information audio	OUI	NON incompréhension	NON	OK	NON	NON
23,53	NON incompréhension du pilote	OUI immédiatement (eye tracking)	(1-3s)Perte de temps lié à la vérification de l'ALT	ecart de calage altimétrique	NON	NON surcharge d'information audio	OUI	NON incompréhension	NON	OK	NON	NON Saturation audio
35,49	NON incompréhension du pilote	NON	/	ecart de calage altimétrique	NON	NON surcharge d'information audio	OUI	NON incompréhension	NON	OK	NON	NON Saturation audio
20	NON incompréhension du pilote	OUI immédiatement (eye tracking)	(1-3s) Perte de temps lié à la vérification de l'ALT	ecart de calage altimétrique	NON	NON surcharge d'information audio	OUI	NON incompréhension	/	OK	NON	NON SATURATION AUDIO

Review

- **Scenario-based design → solid conceptual models :**
  - PRODEC method that supports Human Systems Integration (HSI)
  - This method cannot be used without a deeper understanding of what HSI is about!
  - HSI needs to be supported by an expert…
- **Development of a model and metrics for trust and collaboration :**
  - Instant versus cumulative trust: gaining and losing trust
  - subjective measures predominate in the model
- **Taking into account the context through PILOT COGNITIVE ENGAGEMENT INDEX :**
  - Can be used in real time
  - Adapts trust and collaboration metrics over time
- **Optimize VA development**

Use case presentation

Your objective

Use the PRODEC METHOD for an air-air mission scenario :

- Define AS-IS model
  - **Functional analysis**
- Define TO-BE model :
  - **Function allocation**
- Suggest metrics to assess performance, teaming (trust, collaboration, coordination, cohesion), situation awareness.
- Prepare a 10-minute speach to present your work on Friday morning (what did you learn? What were your discussions and reflections?).

Air to air engagement principles

MISSIONS:

- **CAP**: Combat Air Patrol (Aera protection)
- **Sweep** (Suppress opponent force)
- **Escort** (Protect friendly package)

DIFFERENT PHASES:

- Observe the Air to Air picture to get **Situational Awareness** (SA) on the current air operation,
- Check opponent skills/intents
- **Survive** : Avoid opponent shots & update permanently your SA (sensors)
- Wait for opportunity and do not create opportunity for the opponent
- **Suppress** or move aside opponent force

Tools:

- Radar (RDR)
- Radar Warning Receiver (RWR): Scan, Track, Acquire & Fire modes (depending on the threat)
- Radio
- Other sensors (Laser tracking, IR sensor...etc.)
- Data Link (L16)
- Electronic Counter Measures

Air to air scenario : AVOIDING THREAT ON RWR INDICATION

Use Case description :

- Coalition package with differents roles (Strike & Air to Air missions) => In between Coordination
- Tactical situation with Ground to Air & Air to Air threats

- Blue Means :
  - Striker formation : **F14B (subject to be studied)**
  - Sweep formation : Gives air superiority to blue package
  - Escort formation : Ensures close protection of F14B formation

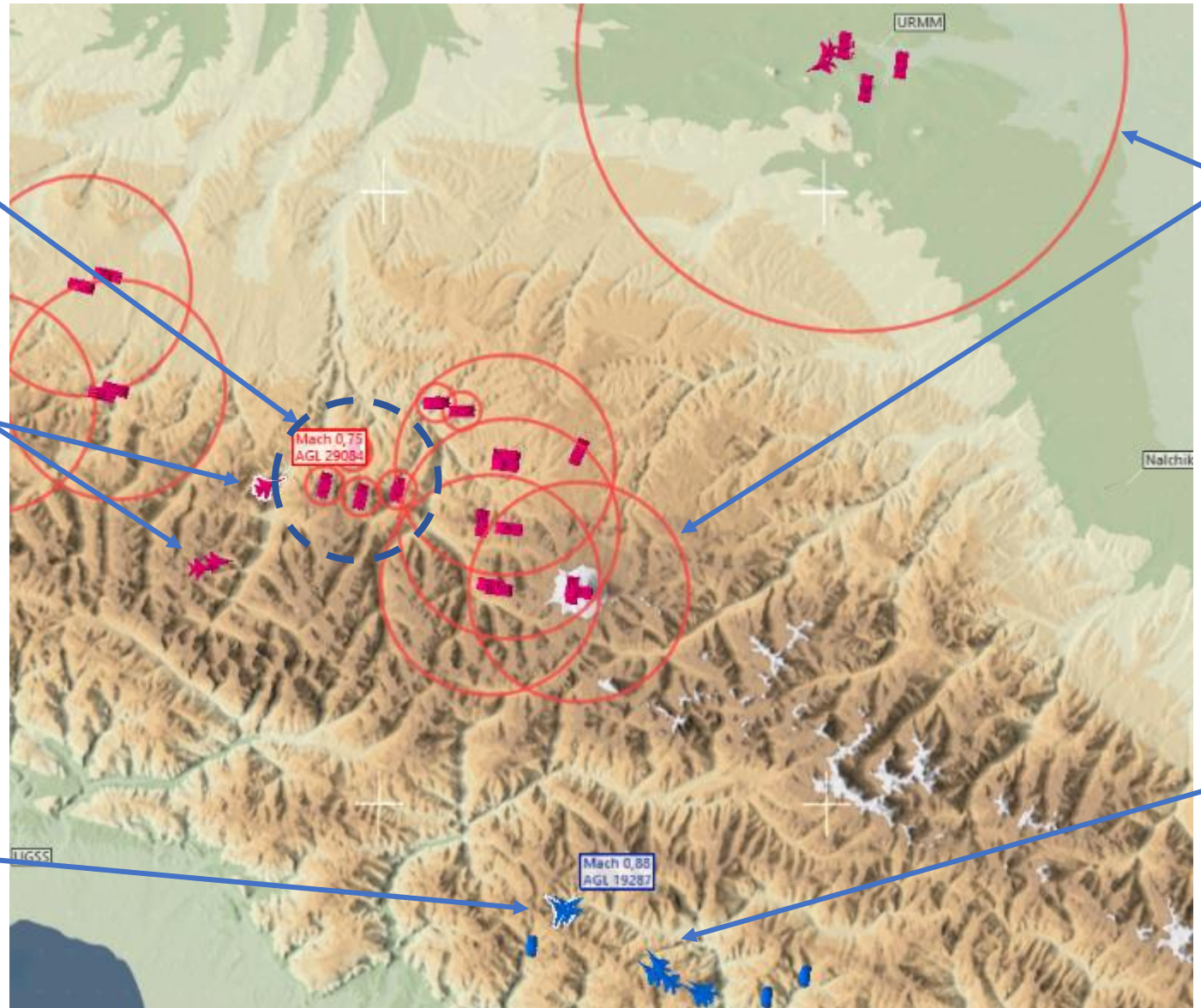
- Tasks :
  - Striker: Destroy C2 command post in the deep ennemy area
  - Sweep: Maintain opponent forces aside of Striker's vicinity or destroy them
  - Escort : Destroy all opponent approaching Strikers formation

Air to air scenario : AVOIDING THREAT ON RWR INDICATION

TARGET AREA (MISSION OBJECTIVE)

GROUD TO AIR THREAT

F14B (HIGH VALUE)



GROUD TO AIR THREAT

BLUE PACKAGE

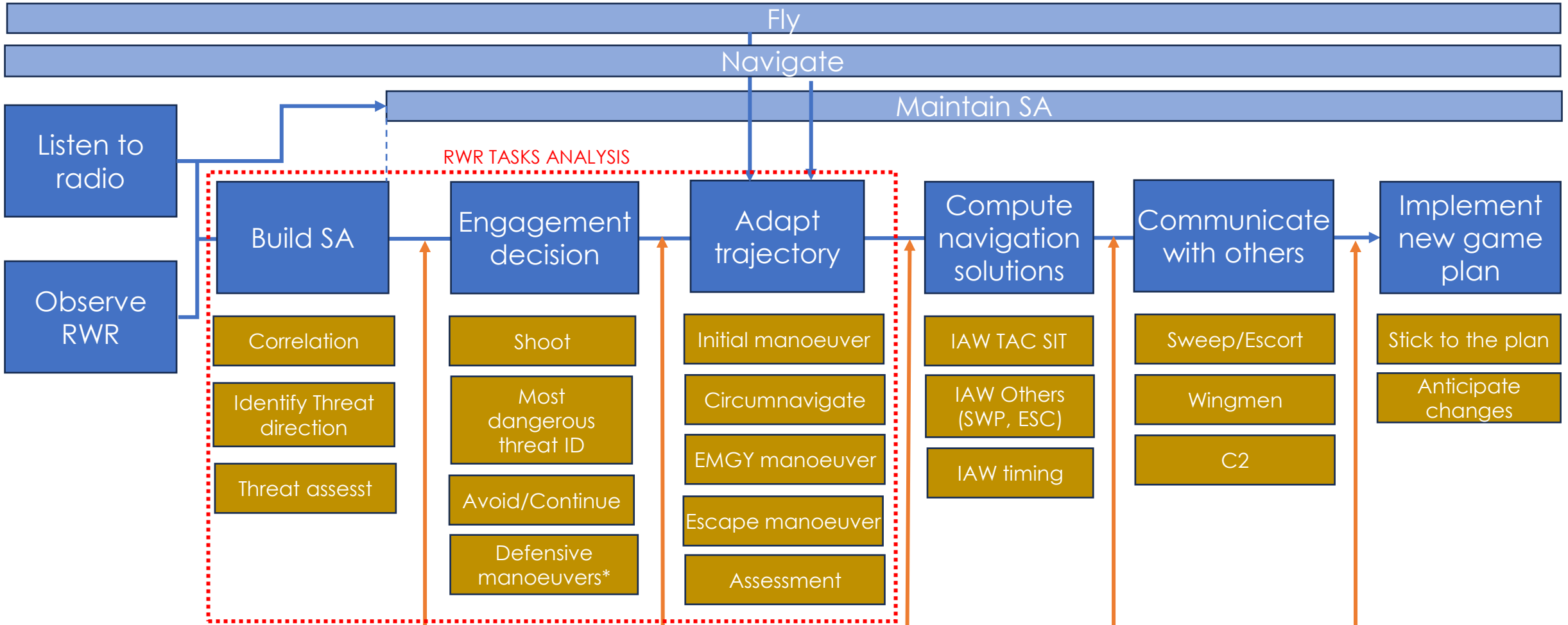
Air to air scenario : AVOIDING THREAT ON RWR INDICATION

Few high level tasks in A/A mission:

- Fly
- Navigate
- Acquire SA
- Enagement decision
- Adapt trajectory
- Compute solutions
- Communicate
- Implement
- …

Air to air scenario : AVOIDING THREAT ON RWR INDICATION

Tasks :



Events:

*Includes ECM