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Human Factors and HMI for Future Air Domain

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Agenda

1. Introduction
2. HMI-HUFLab in Sweden
3. HMI-HUFLab in Brazil
4. Conclusion and Next Steps

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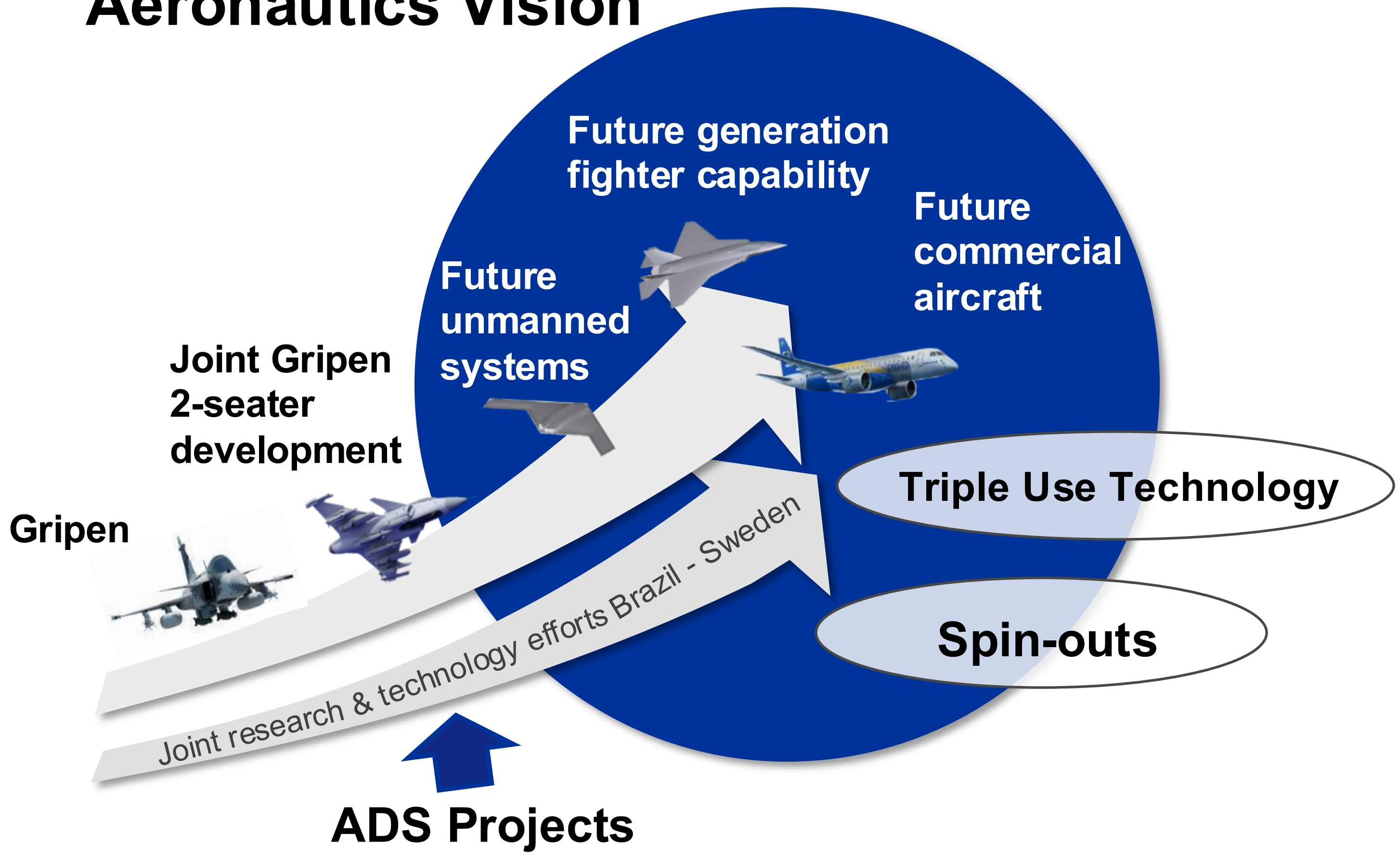
What do we mean by "Future Air Domain"?

- Concept
  - Combination of aerial operations, technologies, and strategic considerations that will shape how air power is projected and managed.
- Relevance:
  - Air Domain is critical for success across land, sea, and space operations.
  - Air Domain is vital for economy, science, and humanitarian efforts (ex: trade, disaster response).
- Key features:
  - System of systems:
    - Integration of next-generation aircraft with drones;
    - AI enabled real-time data collection and processing;
    - Collaboration with legacy platforms.
  - Manned-Unmanned Teaming (MUM-T):
    - Shift beyond traditional pilot or operator roles.
    - Humans will collaborate dynamically with intelligent agents.
    - Operations will span human-in-the-loop, on-the-loop, and out-of-the-loop modes.

The Air Domain Study (ADS) Program

The Brazilian–Swedish Aeronautics Vision



ADS – Future Air Domain Study Group

- Different levels of autonomy and embedded intelligence
- System-of-systems
- Human-autonomy teaming
- Human-machine interface

ITA · Centro de Competência em Manufatura · Finep Inovação e Pesquisa · FMV · SAAB · LiU · RISE

The HMI-HUFLab Projects

HMI-HUFLab Phase I

How do new human-machine interface (HMI) solutions contribute to improve performance and/or safety?

What are appropriate models and tools to measure the impact of HMI?

To what extent can we use flight simulators to investigate pilot/aircraft interface?

HMI-HUFLab Phase II

How can cognitive modelling and pilot state monitoring contribute to the development of adaptive HMI?

How can physiological sensors and state-of-the-art analysis be used to monitor the pilot?

How does the need to interact/communicate with multiple unmanned aircraft affect the pilot?

What qualities of adaptive HMI for future fighter pilots are important?

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HMI-HUF Lab II in Sweden: *Research questions and proposals*

How can cognitive modelling and pilot state monitoring contribute to the development of adaptive HMI?

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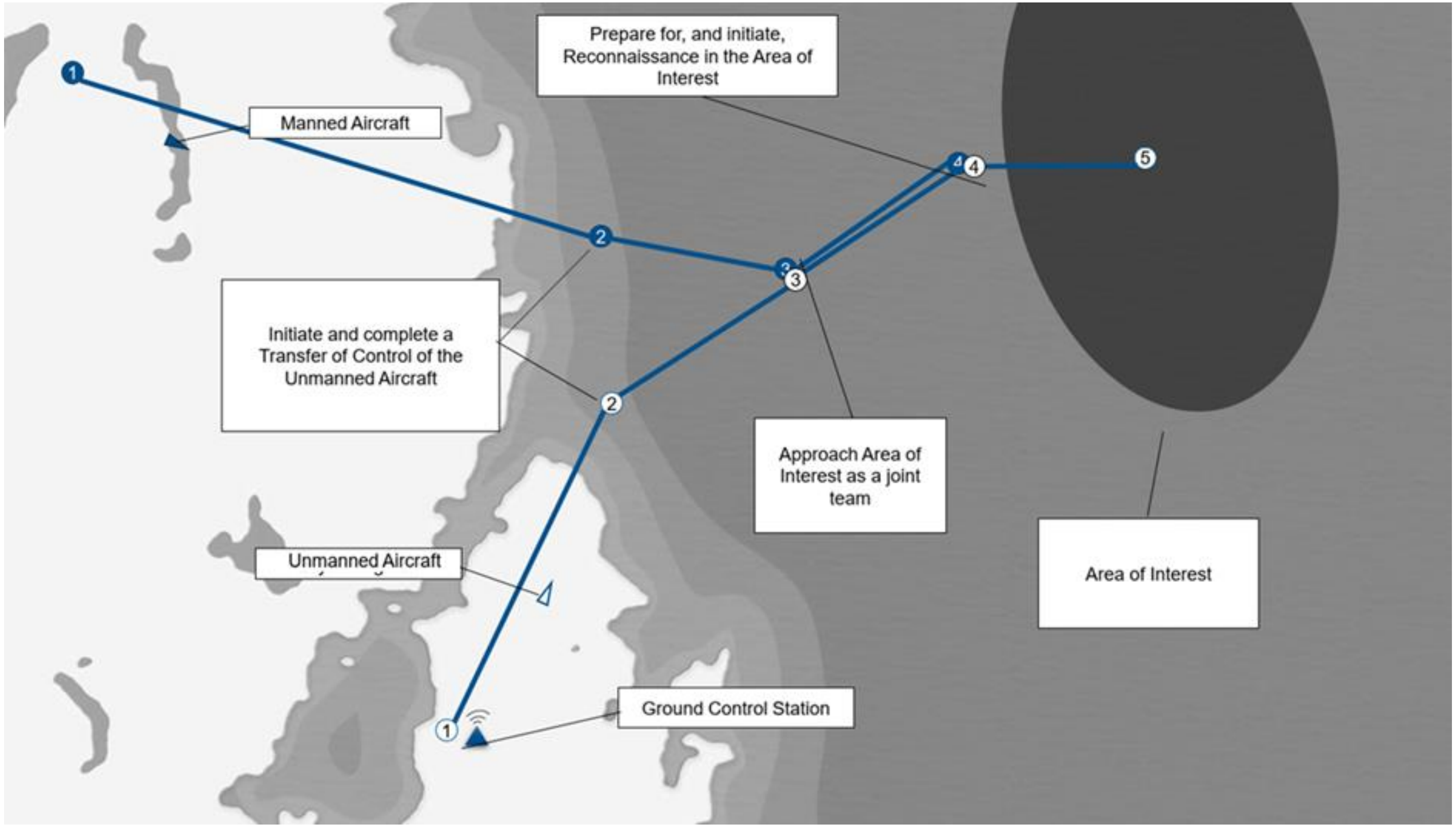
Conceptual Prototypes - SWEDEN

- P1-SE: Design based on Pilot Intent Models
- P2-SE: Pilots Interacting
- P3-SE: Swarm Interaction

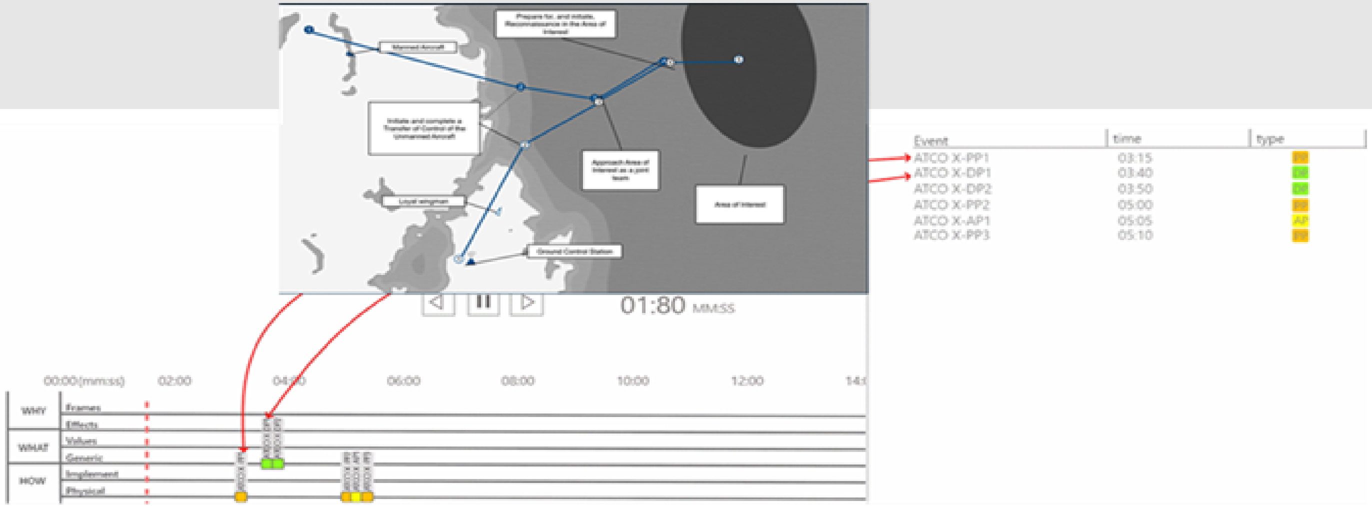
Prototype P1-SE

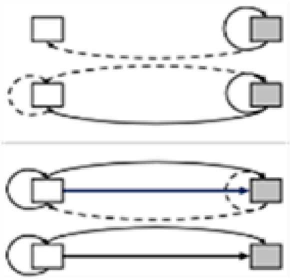
- **Design Based on Pilot Intent Models**



Prototype P1-SE

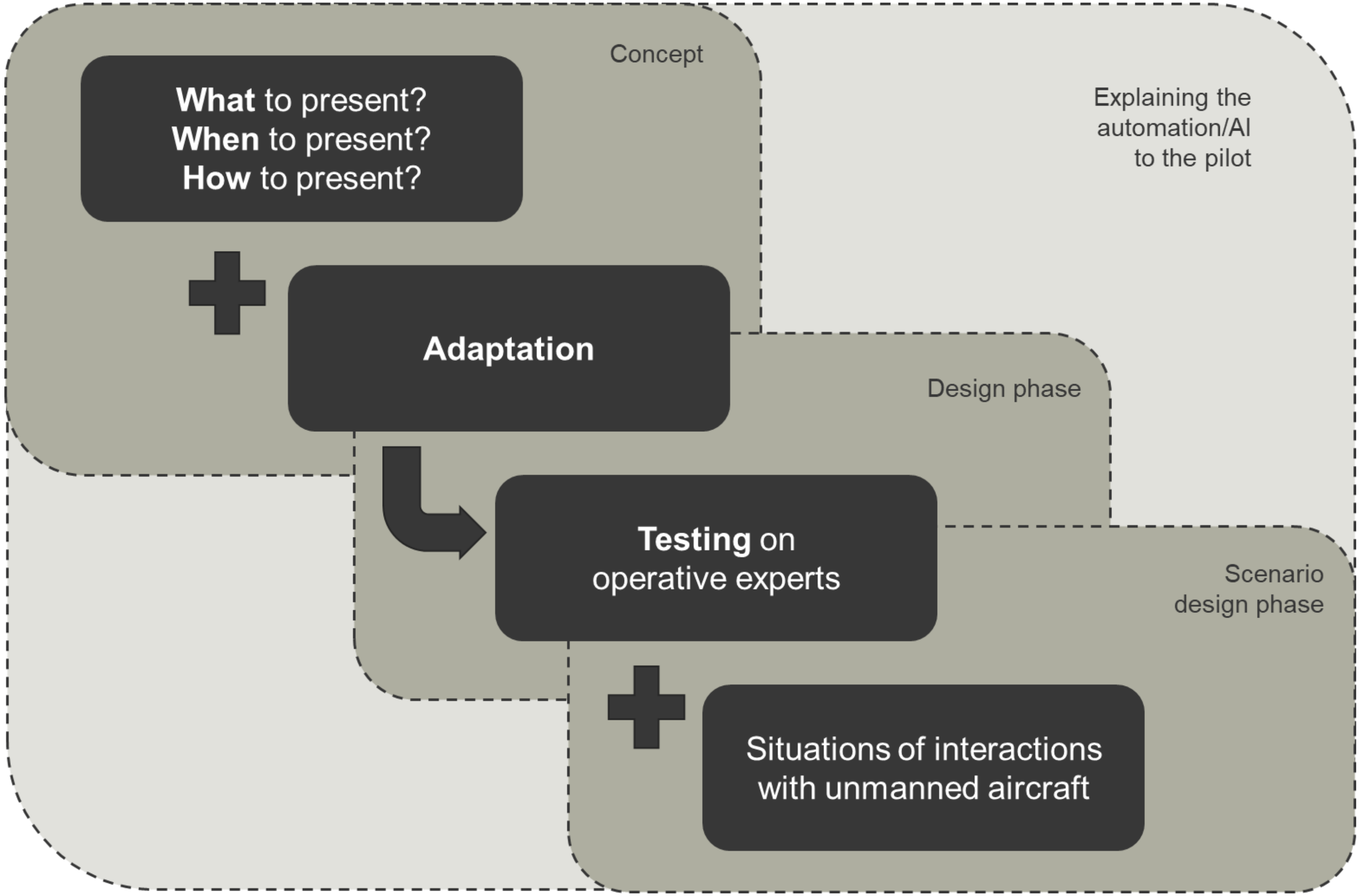
- **Design Based on Pilot Intent Models**





	LACC	Description
Why	Framing	Committing to a specific frame separates a situation from its context, and provides an understanding as well as purpose (e.g. mission purpose).
	Effects	Commitment to situated desired state-of-affairs to accomplish or maintain (e.g. mission objective)
What	Values	Committing to certain priorities in values (e.g. mission performance, safety, security), as well as situation constraints in order to evaluate and plan.
	Generic	Commitment to situated general plans, considering the values and possible implementations.
How	Implementations	Commitment to certain activities, and their related physical subjects and objects, to achieve plan.
	Physical	Commitment to certain physical subjects (e.g. pilot) and objects (e.g. aircraft), and their situated attributes (e.g. role, capability) in the context

- **Design Based on Pilot Intent Models**

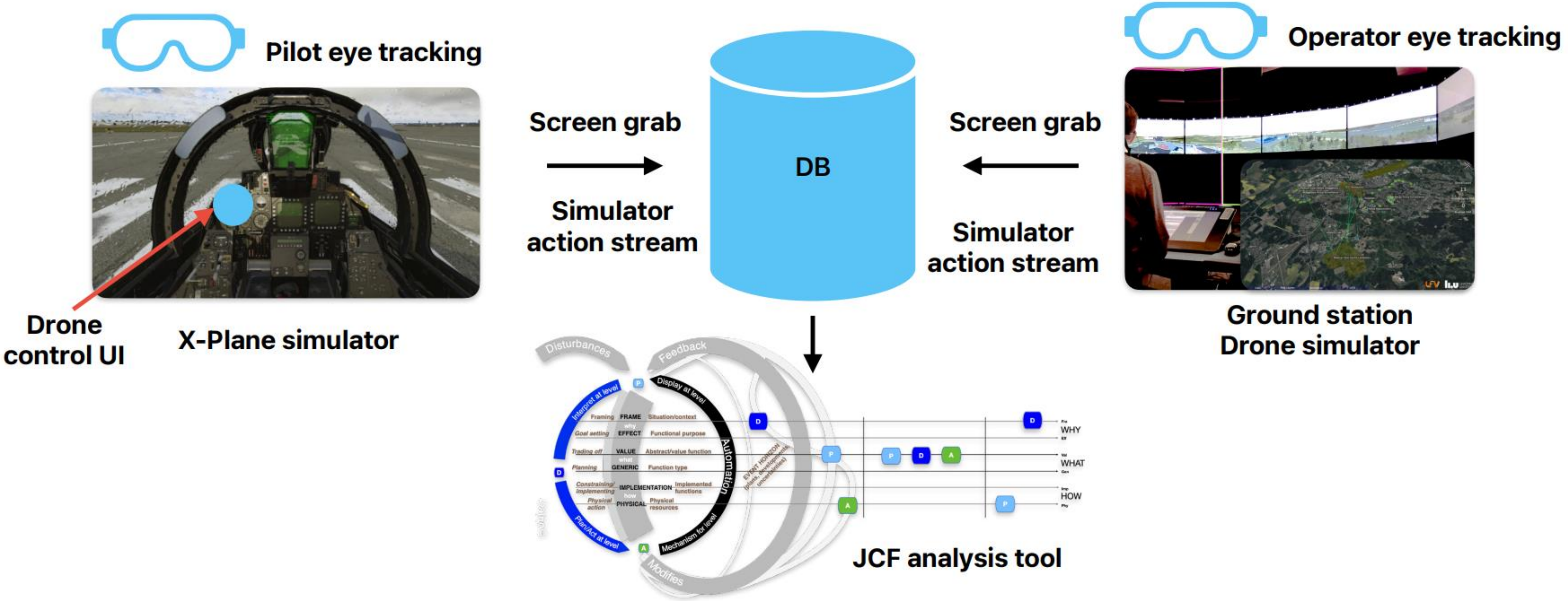


Prototype P2-SE

- **Pilots Interacting**
  - We expect ground control to partly have a different operational picture:
    - Associated with a different role, than the pilot;
    - Especially regarding surrounding traffic and missions;
    - Their event horizon of plans and expected developments may also differ;
    - At times, they will collaborate sequentially by shifting command between them, and at times they may collaborate in working on specific situations requiring a coordinated effort and shifting command responsibilities;
    - Challenges such as coordinating situation awareness for their different needs will be addressed.

Prototype P2-SE

- **Pilots Interacting**

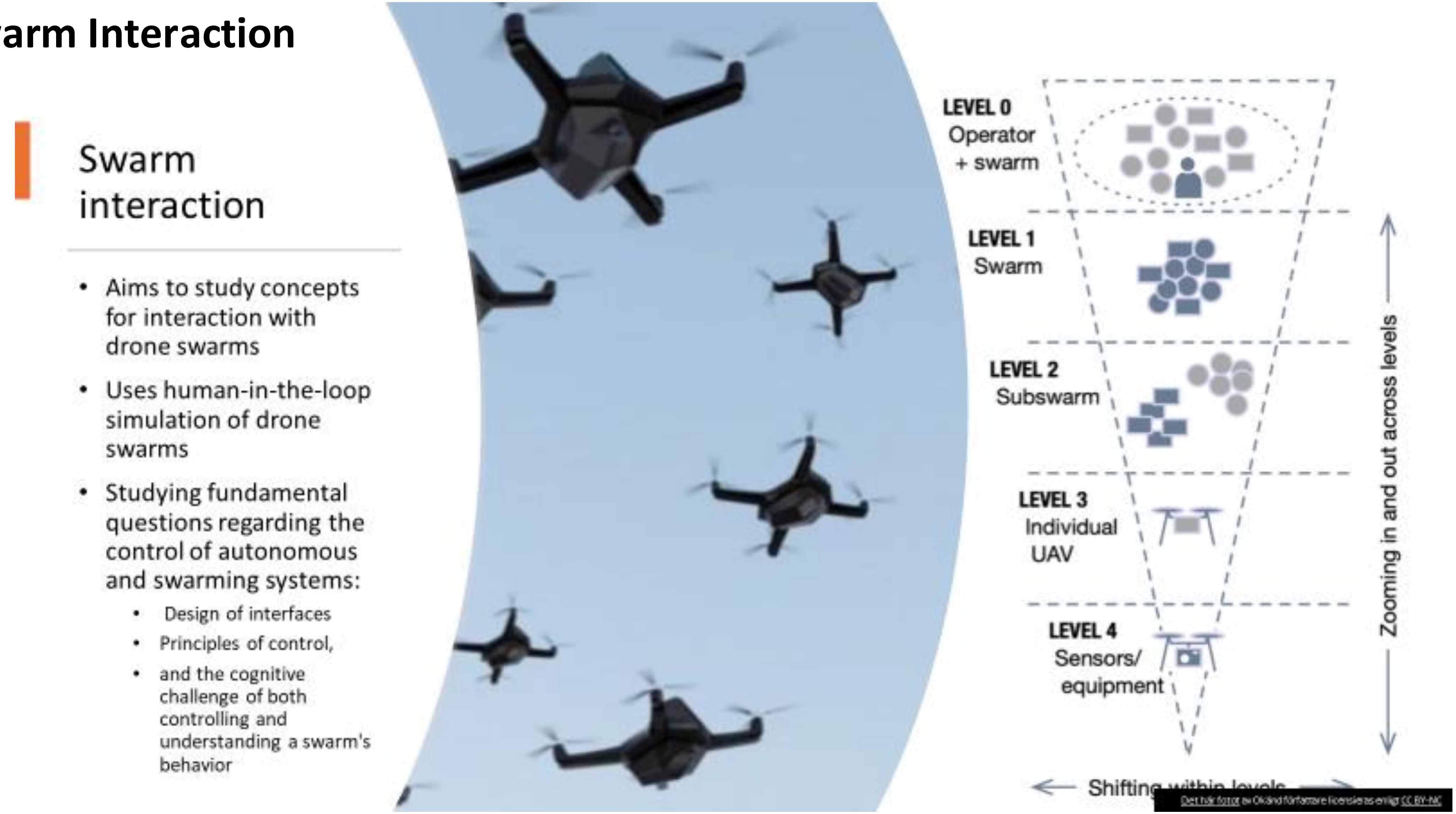


Prototype P3-SE

- **Swarm Interaction**
  - Interface that enables multilevel swarm interaction
    - Direct and indirect control paradigms.
  - Supports high-level mission assignment
    - Visual swarm abstraction
    - Drill-down inspection of individual agents
  - Incorporates task-based grouping
    - Timeline coordination
    - Contextual overlays to assist operator attention management

Prototype P3-SE

- **Swarm Interaction**



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HMI-HUF Lab II in Brazil: *Research questions and proposals*

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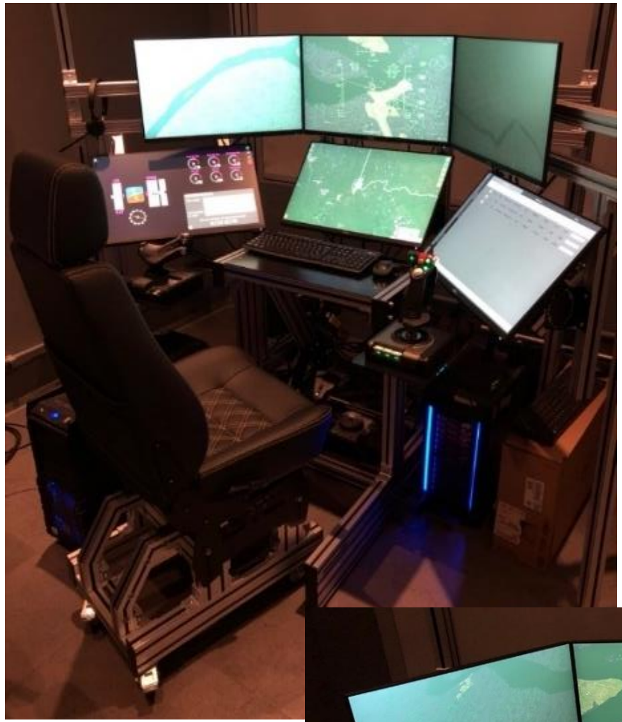
Conceptual Prototypes - BRAZIL

- P1-BR: Predictive control HMI for compensating time delays in UAS-GS communication
  - Context: landing UAS in unplanned location in case of failure and without autopilot.
- P2-BR: HMI with different levels of autonomy for multiple UAS mission reconfiguration
  - Context: UAV failures in SAR mission
- P3-BR: Design of multi-modal interface based on generative AI
  - Context: manned-unmanned teaming in ISR mission

Available Simulation Environments in Brazil



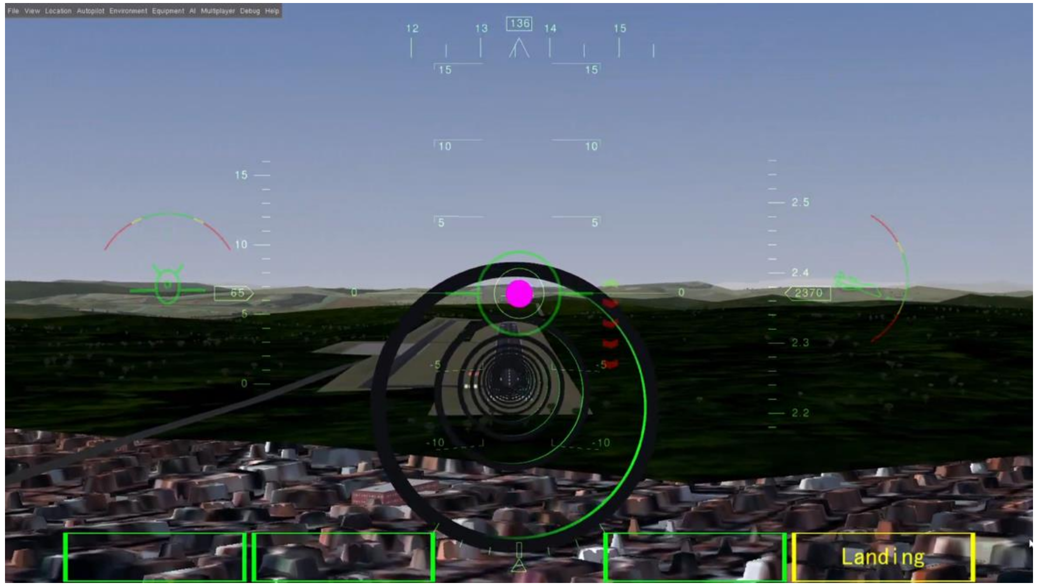
The CAVE –
GCS Simulator

The SIVOR –
Flight Simulator

Prototype P1-BR

- **Predictive control HMI** for compensating time delays in UAS-GS communication
  - Evolution of a previously designed interface based on contribution from users and experts.
- **Scenario:**
  - UAV needs to switch from an autonomous operation mode to a directly piloted operation mode, given the occurrence of an emergency.
- **Purpose:**
  - Evaluate the use of physiological sensors for pilot monitoring;
  - Investigates the pilots' ability to control the UAV in the presence of communication time delay;
  - Evaluate contribution of predictive interface.
- **Status:**
  - Prototype implemented, evaluation campaign executed, on going data analysis:
    - What is the best HUD from the perspective of subjective workload assessment, physiological sensor and performance metrics?
    - Are subjective workload assessment, physiological sensor and performance metrics correlated?

Prototype P1-BR

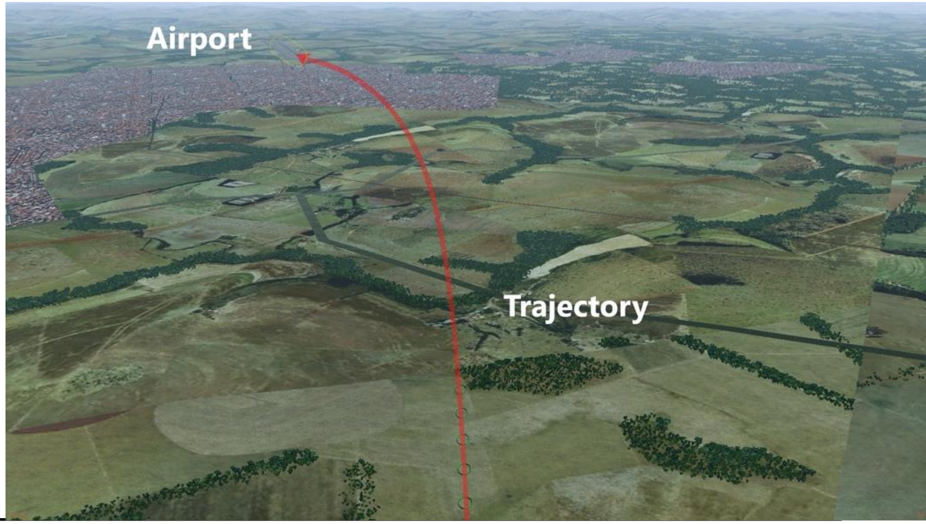


HUD with the predictive display – Version 1

Experimental setup

HUD with the predictive display – Version 2

Landing scenario



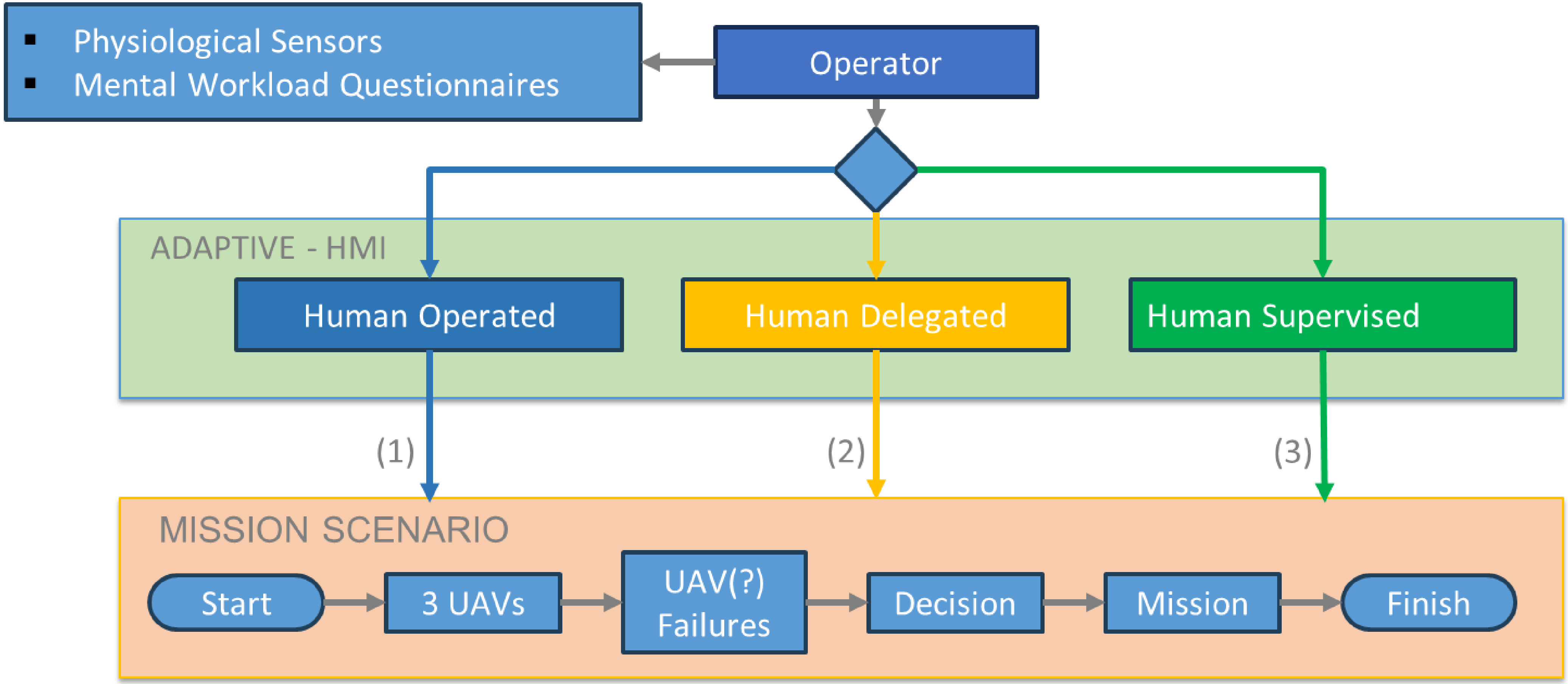
Prototype P2-BR

- AI-assisted HMI with **different levels of autonomy** for multiple UAS mission reconfiguration
  - Investigate the impact of adopting different levels of autonomy
  - Investigate how the pilot workload can be estimated using different tools

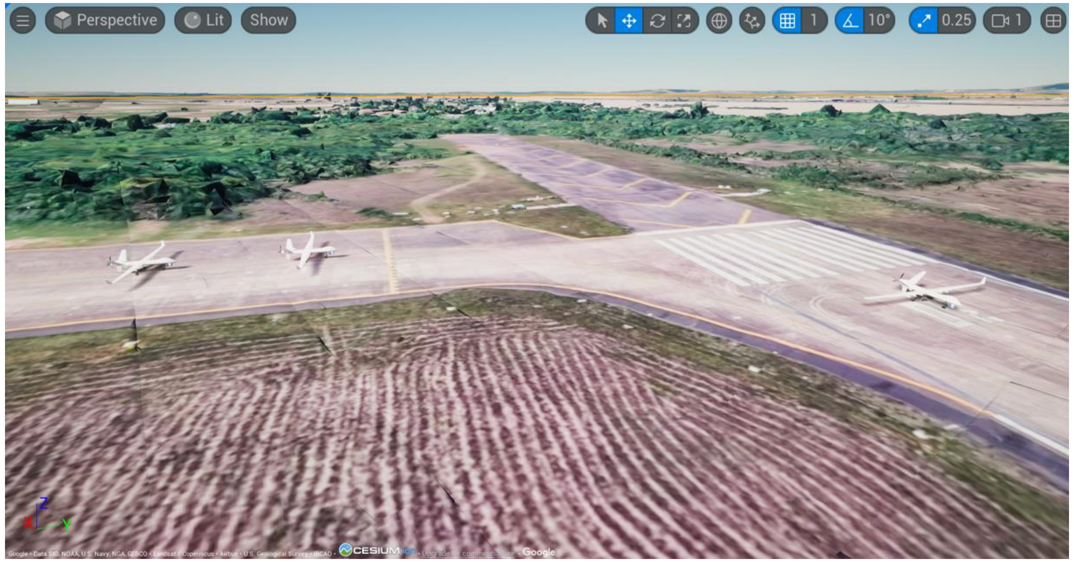
- **Scenario:**
  - A single pilot in a GCS controls multiple UAVs in a SAR mission. The pilot has to monitor the UAVs camera and detect anomalies.
  - An unexpected failure occurs affecting at least one UAV, which may have to return to the base or operate with a degraded performance.
  - The mission needs to be reconfigured. Three options will be tested and compared:
    - Human Operated (manual reconfiguration)
    - Human Delegated (pilot choose among a set of options provided by the AI)
    - Human Supervised (the AI choose and informs the pilot, which may interfere or not)

Prototype P2-BR

- **Experimental evaluation:**

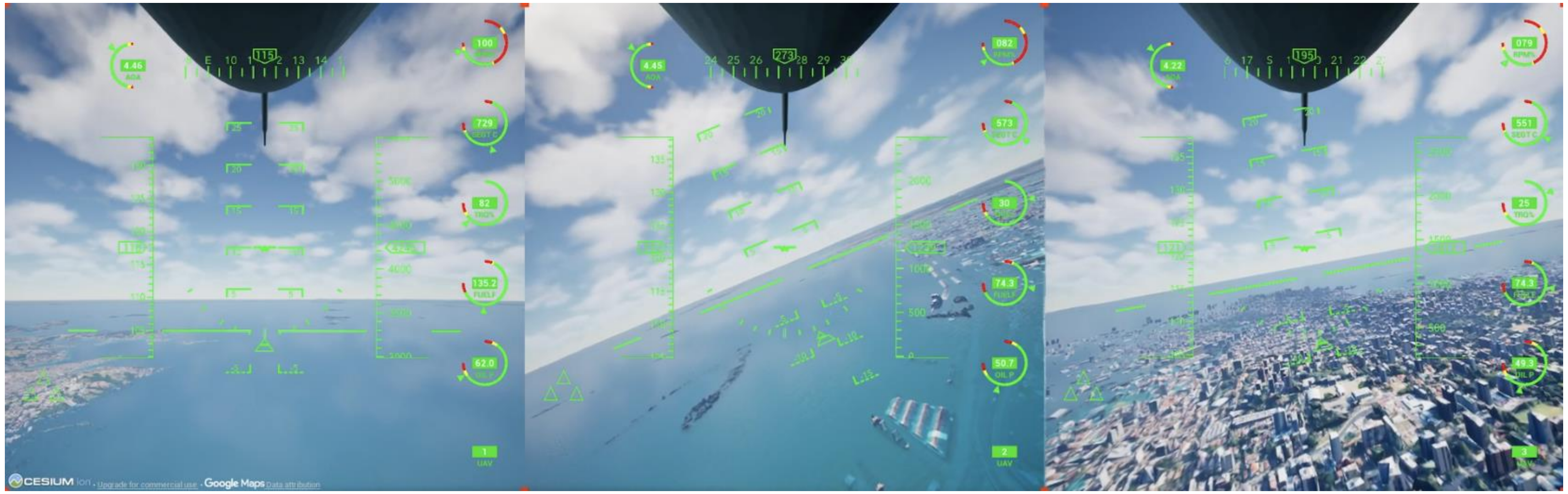


Prototype P2-BR



3 UAVs management scenario

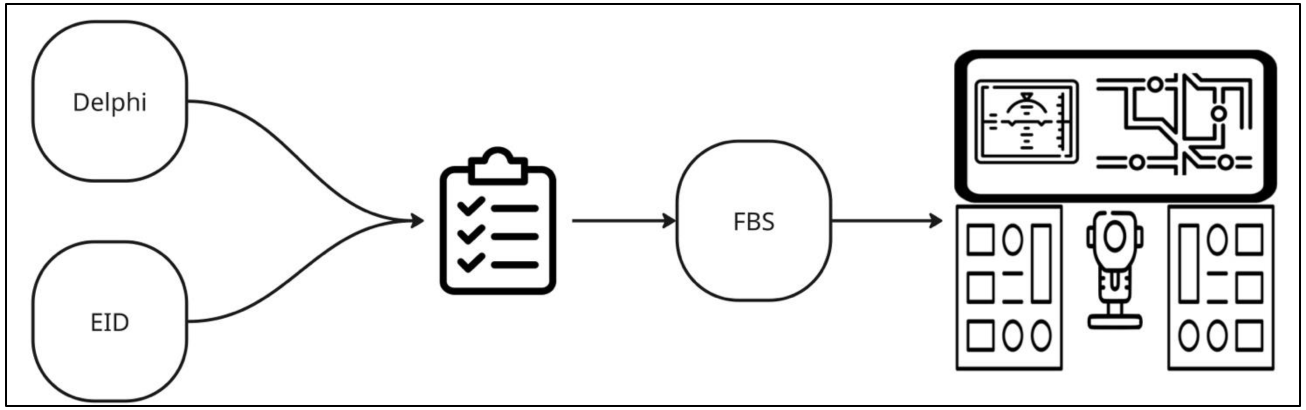
HMI for UAV managing



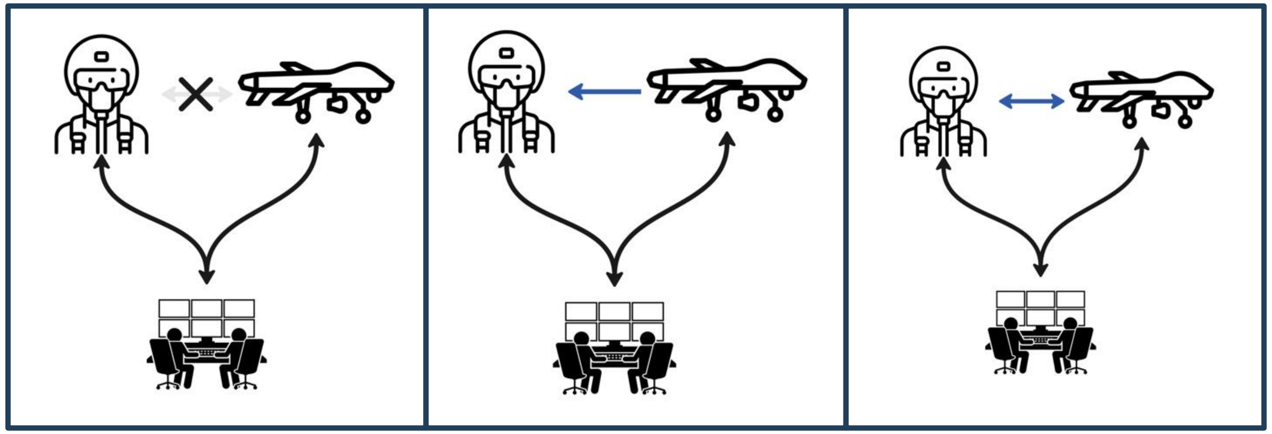
Visualization of the 3 UAVs

- Design of multimodal interfaces based on generative AI
  - Multi modal HMI: speech, touch, gestures, eye movement, physiological signals, sound, vision, vibration, physical elements, touchscreen elements.

- Framework that integrates 3 design methods:
  - Delphi
  - Ecological Interface Design (EID)
  - Function-Behaviour-Structure (FBS)



- **Evaluation Scenario**
  - Border **surveillance and reconnaissance mission** near the northern Brazilian border performed by a fighter jet and a set of UAVs.
  - Use of touchscreen in wide display



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Conclusions and Next Steps

- **Future Air Domain** emerging technologies explored in **HMI-HUFLab II** conceptual prototypes:
  - Manned-unmanned teaming.
  - Adaptative HMI
  - System of systems
  - AI and autonomous systems
- **Human factors challenges:**
  - Cognitive modelling, pilot state monitoring, HMI design.
- **Next Steps:**
  - Conclude implementation of the 6 HMI conceptual prototypes
  - Perform experimental campaigns.

Thank you!

Questions?