



TAPAS: Capacity on-demand using Explainable Artificial Intelligence

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Co-funded by
the European Union

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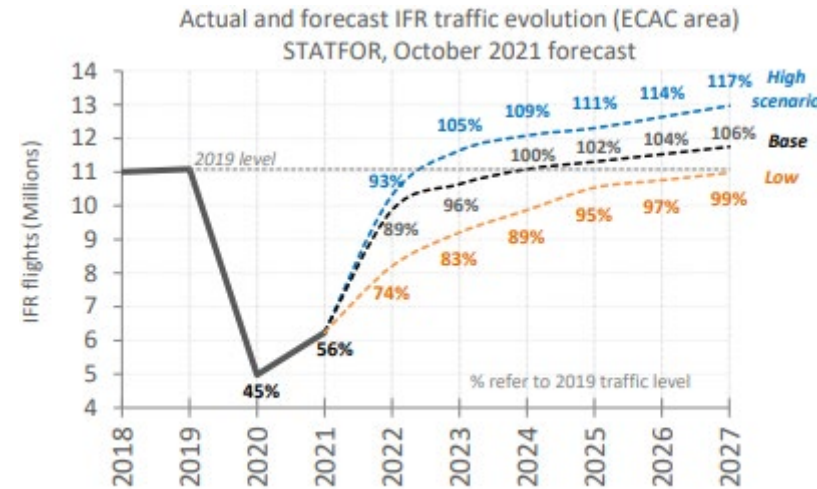
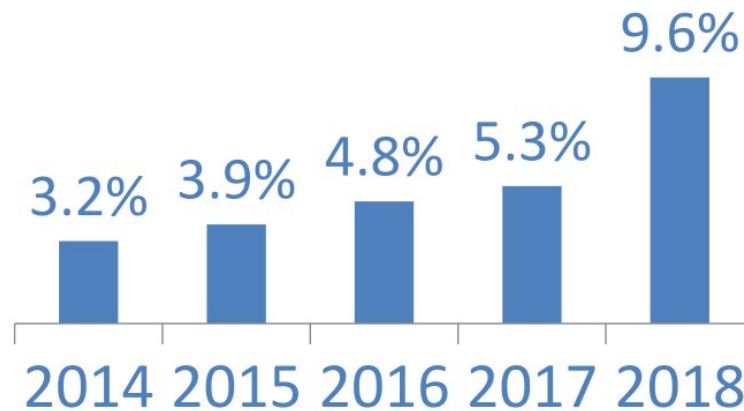
The Consortium



What is TAPAS about?

- ATM system very close to saturation point

Share of en-route ATFM delayed flights (%)

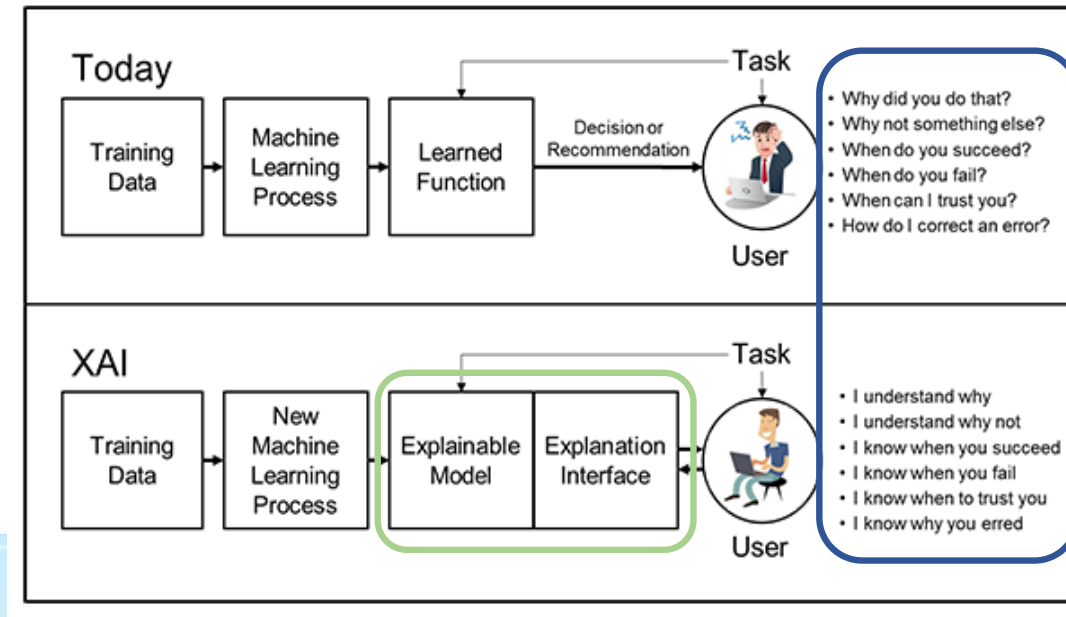


Most priority need: Capacity -> Higher levels of Automation, as key enabler

What is TAPAS about?

- Introduction of AI/ML techniques as a mean to achieve higher levels of automation
- But... this brings new challenges: ATM is a safety-critical domain, where operators need to rely in the system, which in previous experiences is not trivial
- TAPAS: *Towards an Automated and exPlainable ATM System*
- Focus on transparency of AI/ML models applied in ATM use cases (highest priority to enable adoption of these technologies)

Topic SESAR-
ER4-1-2019,
“Digitalisation
and Automation
Principles for
ATM”



*This is conceptually
TAPAS' goal, oriented
to not just a particular
case but trying to
provide a framework
of principles*

Transparency

- Explainability can be, in this context, understood as Transparency
- In AI decisions is about getting high levels of confidence regarding the veracity of a decision or answer provided by a machine for a given problem
- Not all use cases will require a similar level of explainability: it will depend on several factors, such as safety criticality.



Example: Neural networks tend to provide valuable results, but they are a black-box. When and how they could be applied?

TAPAS will address **two use cases**: Non-Safety critical (ATFM) and Safety critical (CD&R, ATC related)

Automation in ATM

Today
(Baseline)

TAPAS
target

Definition			Definition of Level of Automation per Task				Automation Level Targets per MP phase (A, B-C, D)		
			Information Acquisition and Exchange	Information Analysis	Decision and Action Selection	Action Implementation	Autonomy	Air Traffic Control	U-space services
Actions can only be initiated by Human	Level 0 <i>Low Automation</i>	Automation supports the human operator in information acquisition and exchange and information analysis							
	Level 1 <i>Decision Support</i>	Automation supports the human operator in information acquisition and exchange, information analysis and action selection for some tasks/functions							
	Level 2 <i>Task Execution Support</i>	Automation supports the human operator in information acquisition and exchange, information analysis, action selection and action implementation for some tasks/functions . Actions are always initiated by Human Operator. Adaptable/adaptive automation concepts support optimal socio-technical system performance.							
Actions can be initiated by Human or Automation	Level 3 <i>Conditional Automation</i>	Automation supports the human operator in information acquisition and exchange, information analysis, action selection and action implementation for most tasks/functions . Automation can initiate actions for some tasks . Adaptable/adaptive automation concepts support optimal socio-technical system performance.							
	Level 4 <i>High Automation</i>	Automation supports the human operator in information acquisition and exchange, information analysis, action selection and action implementation for all tasks/functions. Automation can initiate action for most tasks . Adaptable/adaptive automation concepts support optimal socio-technical system performance.							
Action can be initiated by Automation	Level 5 <i>Full Automation</i>	Automation performs all tasks/functions in all conditions. There is no human operator.							

The diagram illustrates the automation level targets for two scenarios: Air Traffic Control and U-space services, across three Mission Phase (MP) segments: A, B-C, and D. The levels are represented by colored dots (blue for human-initiated, dark blue for automation-initiated) connected by vertical lines.

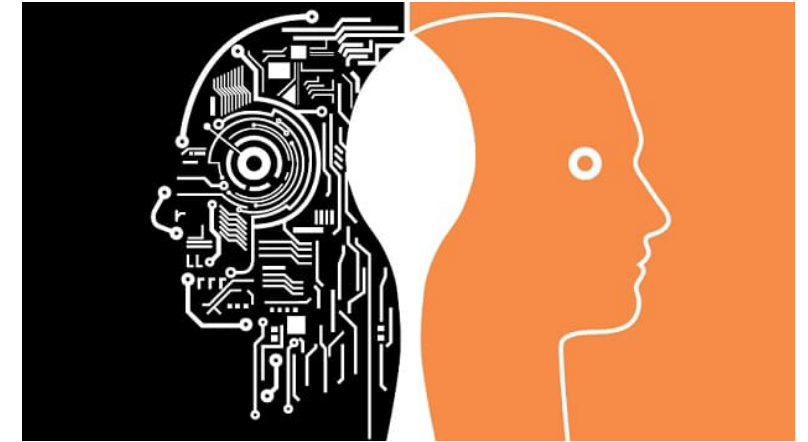
- Air Traffic Control:** Level 0 (Low Automation) is active in phase A. Level 1 (Decision Support) is active in phase B-C. Level 2 (Task Execution Support) is active in phase D.
- U-space services:** Level 1 (Decision Support) is active in phase B-C. Level 2 (Task Execution Support) is active in phase D.

Degree of automation support for each type of task



Human-Centric ATM

- Explainability linked to the idea of human-centric AI
- Progressive evolution of the breakdown of tasks between human and machine
- Machines are good at:
 - Long, monotonous tasks
 - Assembling information to reach decisions
 - Finding patterns and trends
 - Fast reaction
- Humans are good at:
 - Holistic perspective
 - Think outside the box
 - Creative solutions



Better together... if combined in a right way

Use cases - ATFCM

ATFCM Functions / Tasks	Automation Level 1	Automation Level 2	Automation Level 3
Traffic Demand Monitoring	Machine	Machine	Machine
Identification of imbalances	Machine	Machine	Machine
Analysis of the imbalances detected	Human	Machine	Machine
Identification of hotspots / optispots	Human	Machine	Machine
Declaration of hotspots / optispots	Human	Human	Machine
Preparation of DCB measures to solve the hotspot - Capacity Measures (sector configuration) - ATFCM Scenarios - Trajectory Measures - ATFCM Regulation - Selection of candidate flights - Analysis of the DCB measure impact – What-if	Human	Machine	Machine
Decision on the DCB measure and flights impacted	Human	Human	Machine
Implementation of DCB measures	Human	Human	Machine
Hotspot resolution monitoring	Human	Machine	Machine

Use cases – CD&R

CD&R (Executive) Functions / Tasks	Automation Level 1	Automation Level 2	Automation Level 3
Assessment of the planned and desired trajectory profile	Human	Machine	Machine
Identification of potential conflicts	Machine	Machine	Machine
Identification of conflict resolution strategies and clearances proposal	Human	Machine	Machine
Clearances implementation	Human	Human	Machine
Conformance Monitoring	Machine	Machine	Machine
Conformance Monitoring Resolution	Human	Machine	Machine

General Project Objectives



Identification of principles and criteria for AI/ML transparency/explainability in ATM domain scenarios

The project explores the use of XAI and VA to apply them in the operational cases considered, through practical experiments and validation activities in simulation platforms.

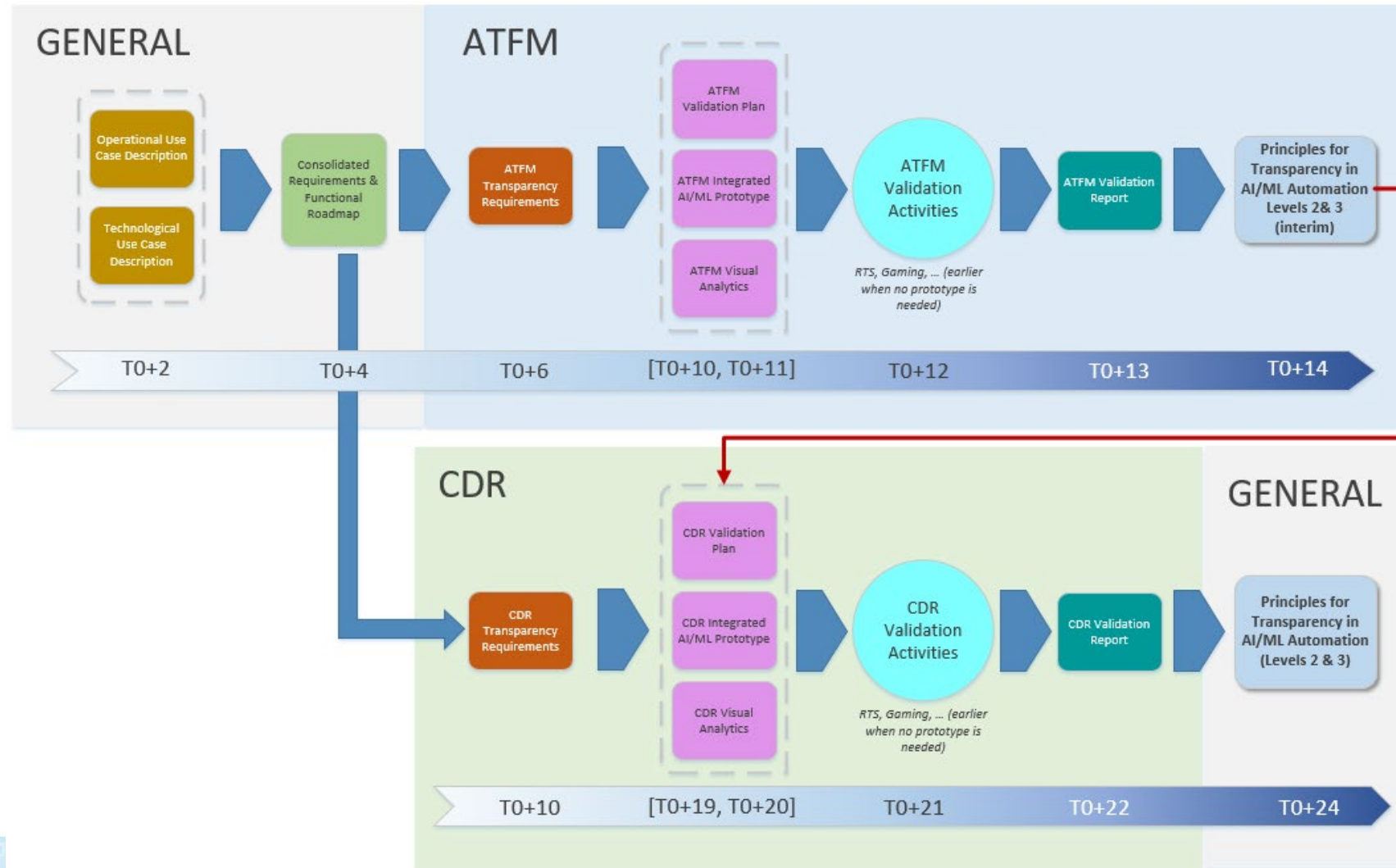
General principles



Selection and development of suitable and explainable AI/ML methods in the operational cases identified, to fit the needs of transparency as expressed in the explainability criteria developed for each automation level and according to actors' needs

Specific examples and prototypes supporting the general principles

The Storyboard



Operational Staff



Participation in use case refinement + requirements
Participation in functional roadmap
Participation in validation & testing activities
Participation in workshops

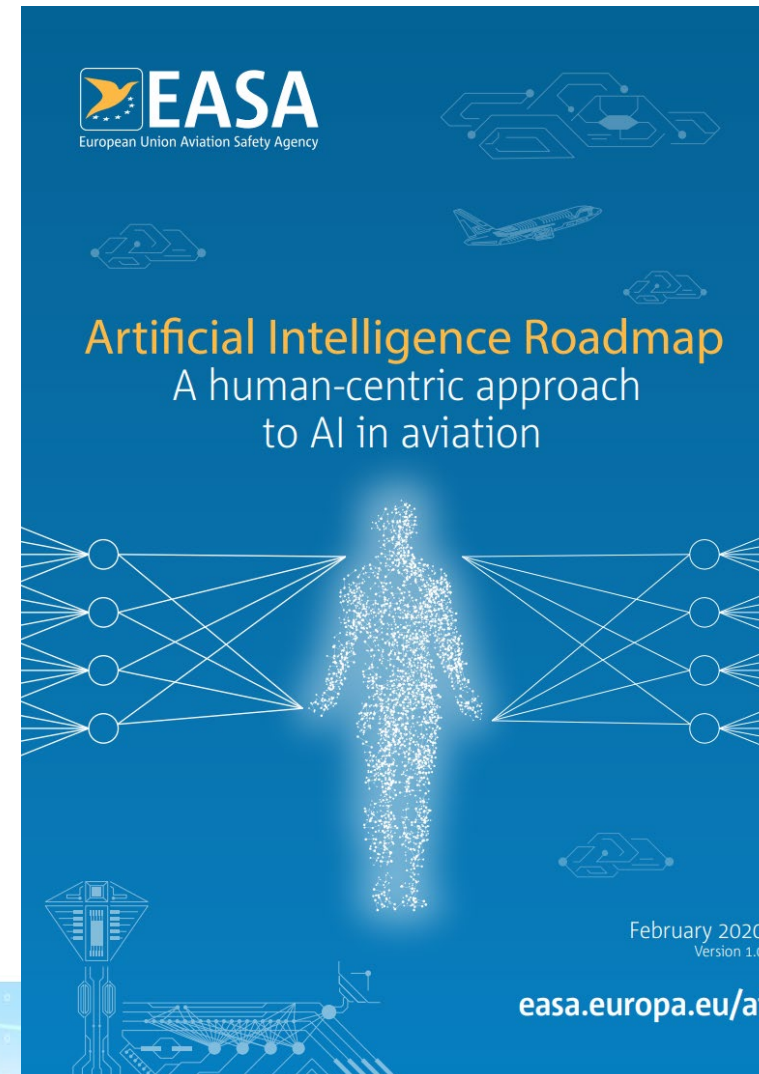
Validation environments



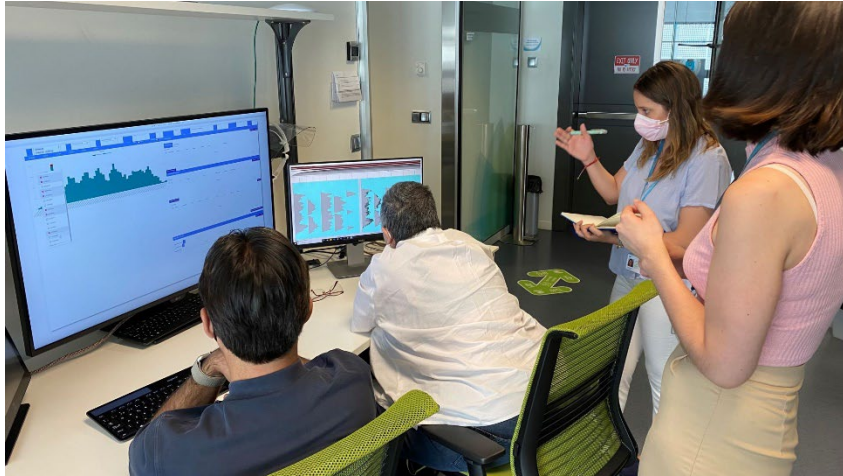
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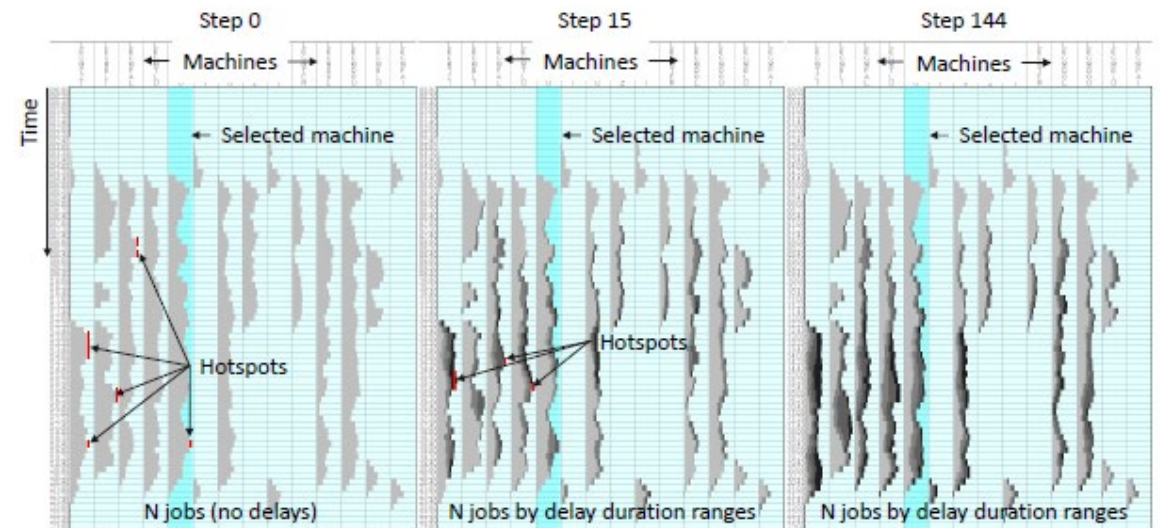
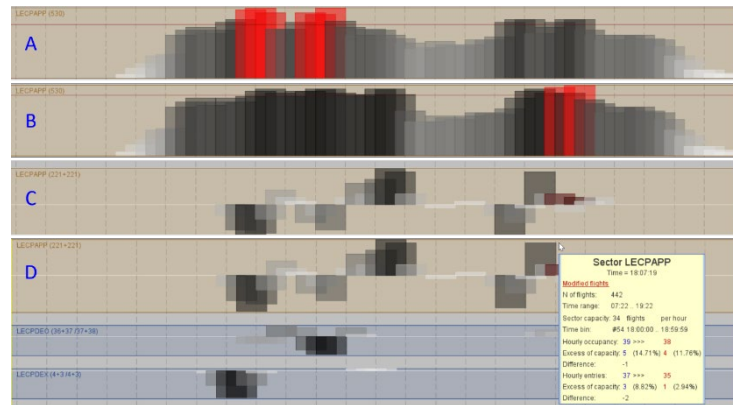
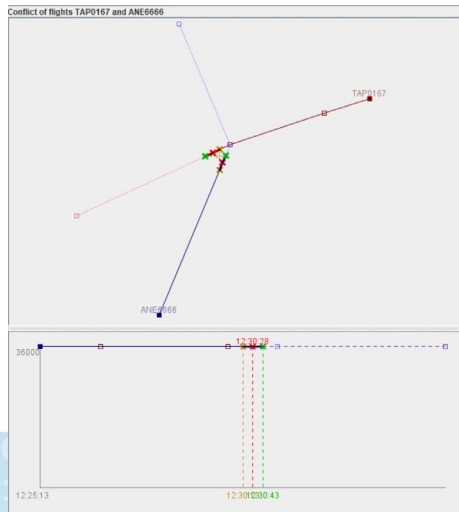
Some background



Experiments with XAI

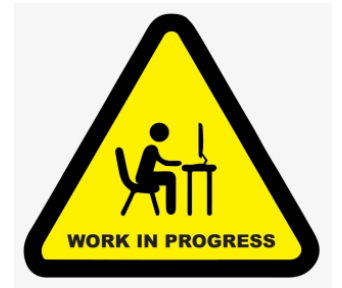


- Prototypes based on a multi-agent system based on reinforcement learning
- Explanations provided visually to ATC by means of **Visual Analytics** combined with **XAI prototypes**



Levels of Explainability

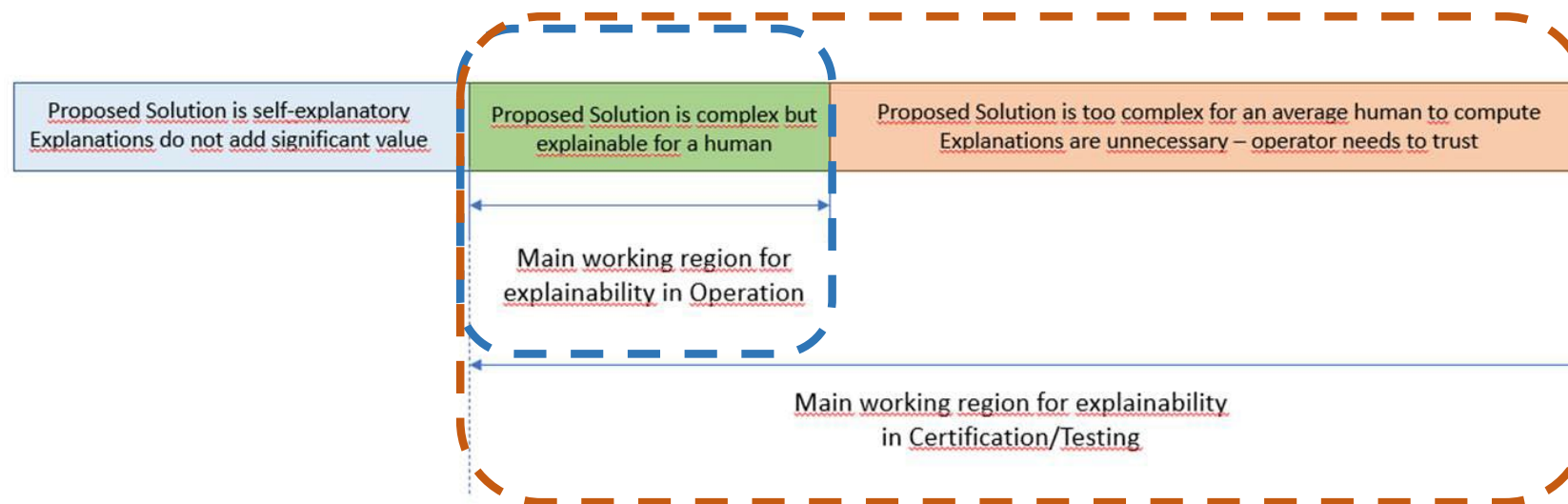
- **Self-explanatory** (no additional information is provided) → *The operator would understand what is proposed intuitively, based on background and expertise*
- **Explainability on demand** (the system may provide additional information to explain the solution reached, available if requested by the operator)
- **Explainability by default** (the system acknowledges the unusual condition of a solution reached and provides by default explanations on it) → *Initial intended use: training & certification*



Not all situations require the same explainability solution: actor (operator, regulator, society), context (certification, training, operation), operational context (safety-critical, strategic/planning...)

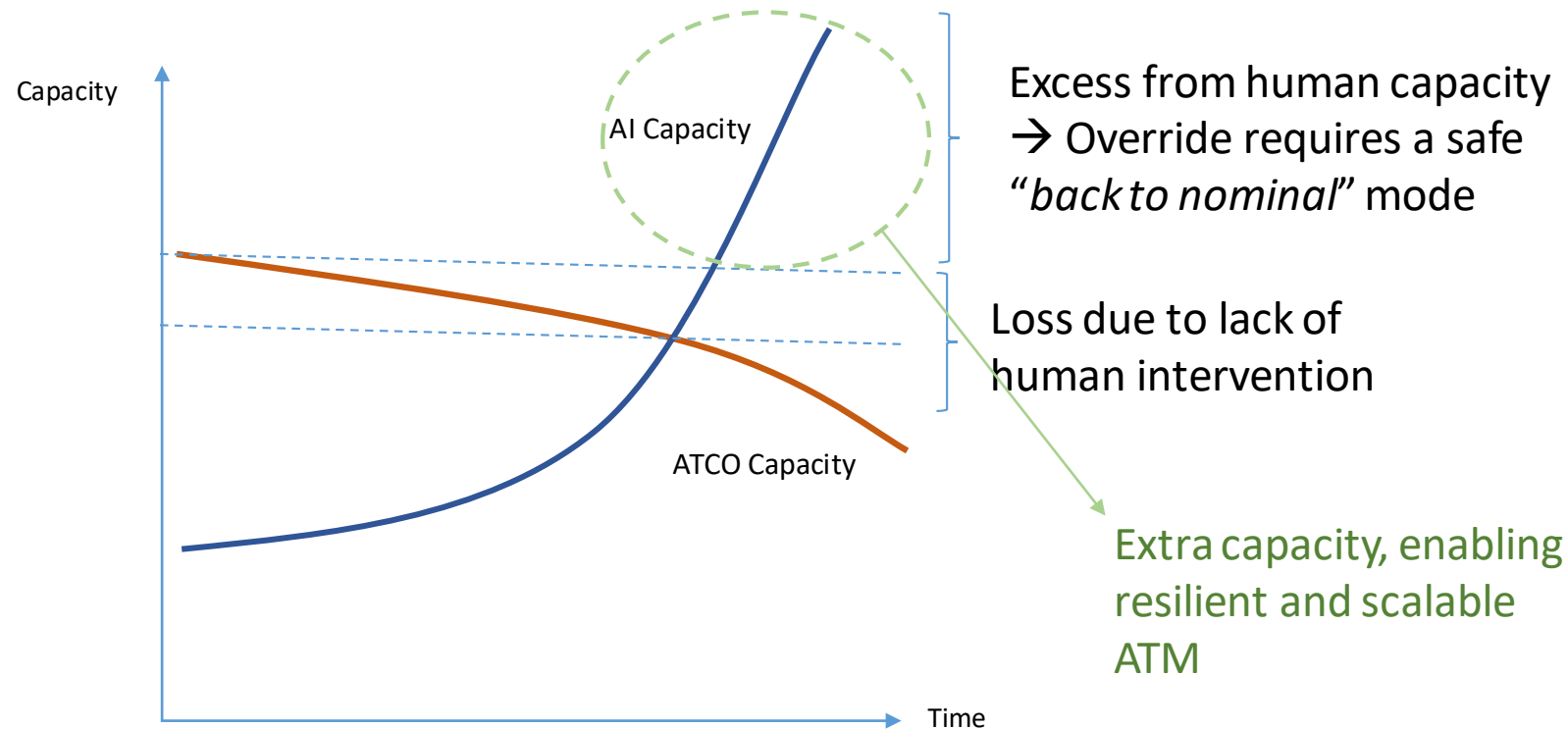
Explainability: Initial findings

- **Trustworthiness** is the best explanation
- Explainability requirements are different: system design & certification, and operation
- Aggregated information: hotspots with ID, total delay, benefited and penalized flights...
- Some solutions are too complex for a human to understand in real time
– *the added value window is limited*



Modes of Operation: Resilience

- Higher levels of automation imply that the system may reach levels beyond the human capabilities to override in a safe and reliable way



New challenges ahead
for uptake of ATM
domain of AI/ML
techniques

THANK YOU



This project has received funding from the SESAR Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No XXXXX



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