IFATCA Guidance Material on Joint Human and Machine System

Prepared by Stathis Malakis
IFATCA JCHMS Team

Presentation Details

Version 1.0

21/3/2024

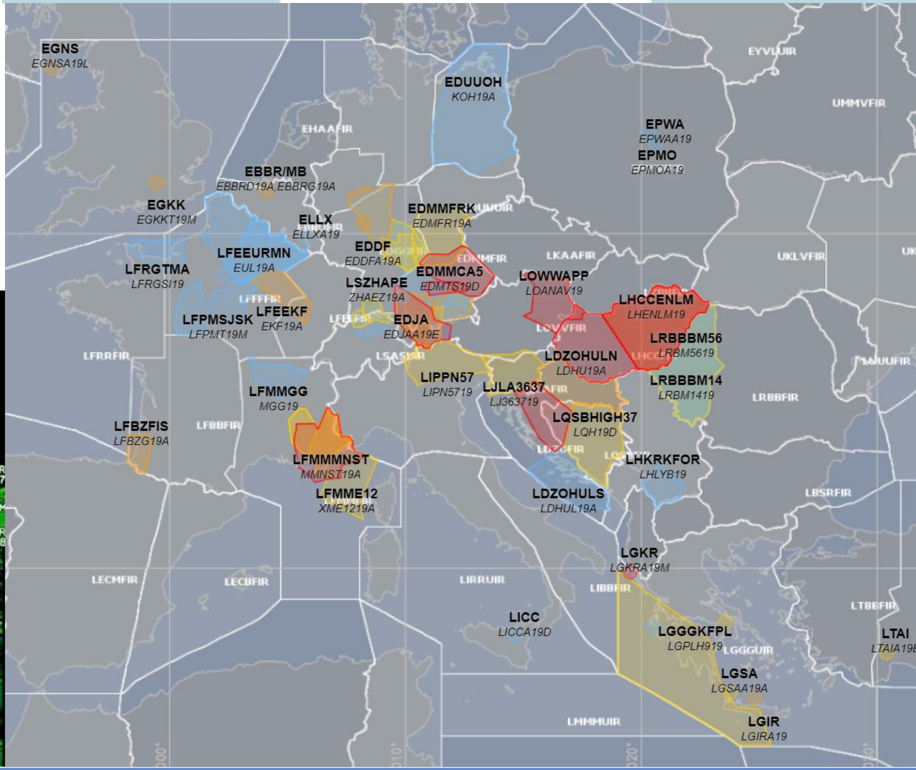
Slides : 24

Origins : Artificial Intelligence and Machine Learning in Safety Critical Domains

Growing momentum for introducing **AI/ML** in safety critical domains (e.g., **ATM**) building upon:

1. Advances in capacity to **collect** and **store massive amounts of data.**
2. Significant increases in **computing power.**
3. Development of increasingly **powerful algorithms** and architectures.

Motivation

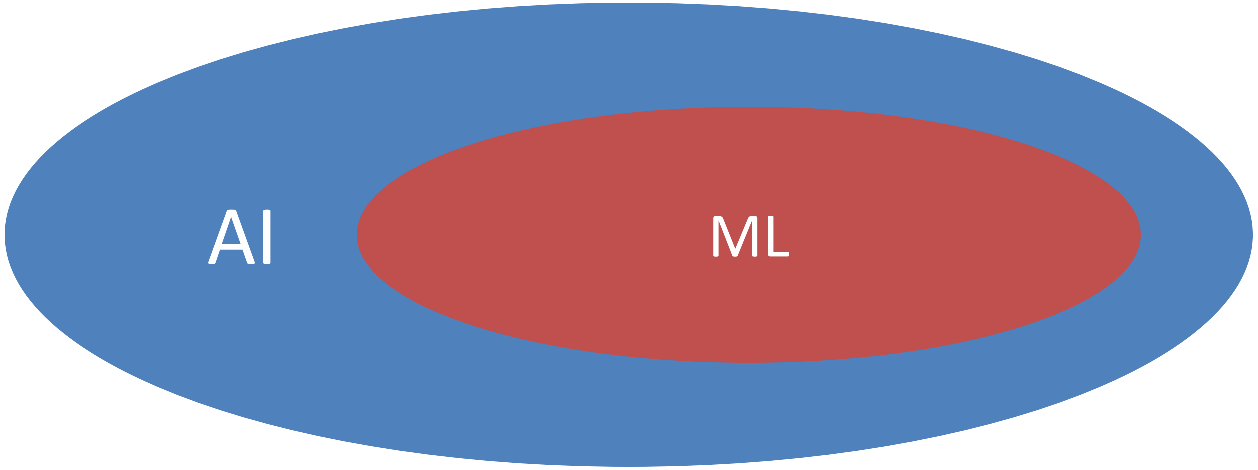


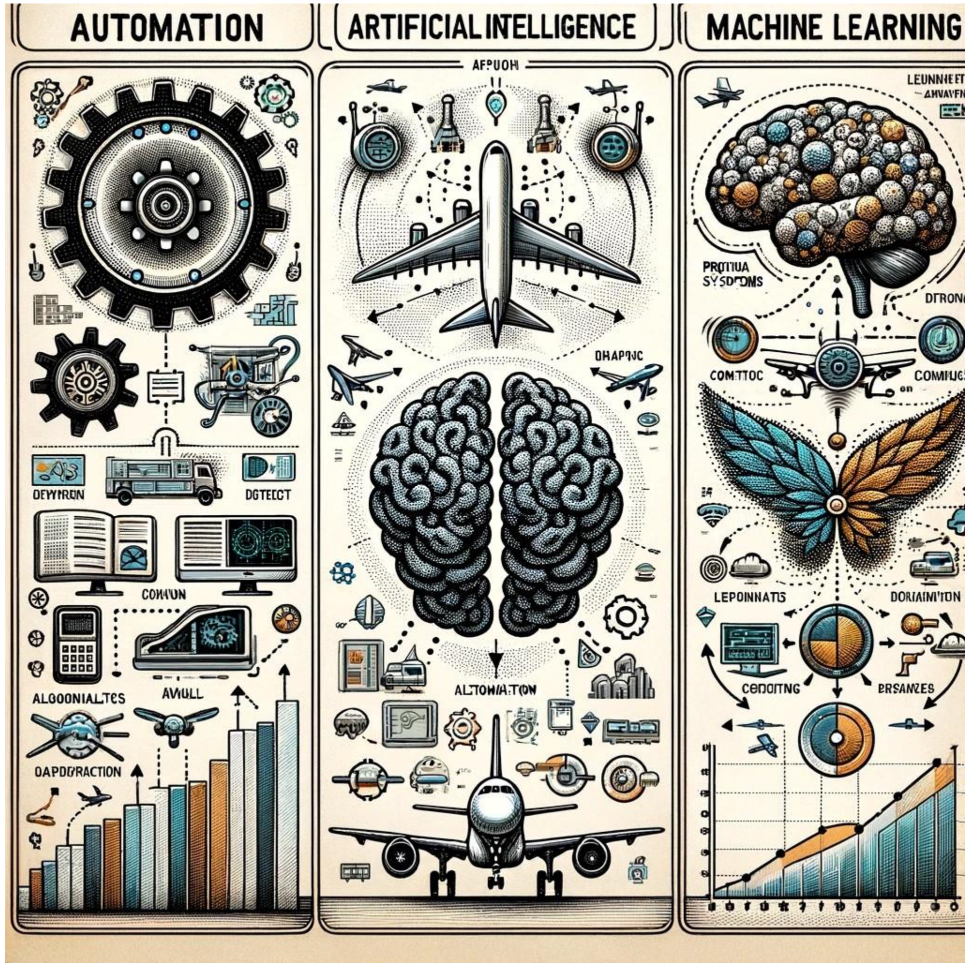
Envisioned AI/ML - driven ATM environment with pressing needs for:

1. Minimization of **delays.**
2. Accommodating a diverse array of **autonomous aircraft.**
3. Operating smoothly in **adverse weather** conditions.
4. Smoothing out **4D aircraft trajectories**, and
5. Minimizing **environmental impact.**

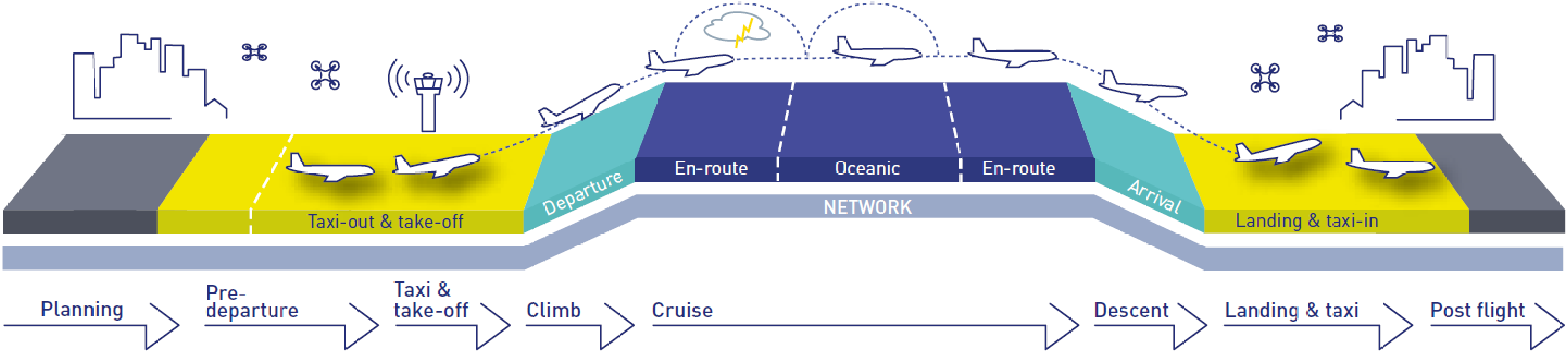
Automation, AI and ML

- ✓ AI is the ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings.
- ✓ ML can be defined as programming computers to optimize a performance criterion using example data or experience.
- ✓ Automation refers to the use of technology to perform tasks that were previously done by humans.



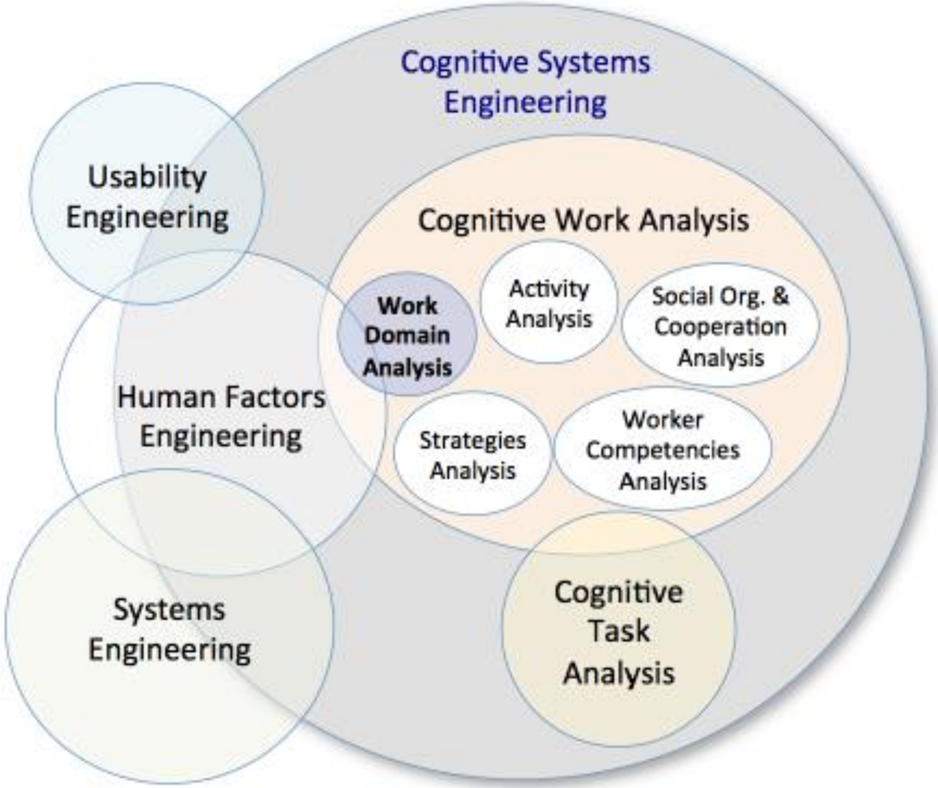


A High-Level Description of the Air Traffic Management System



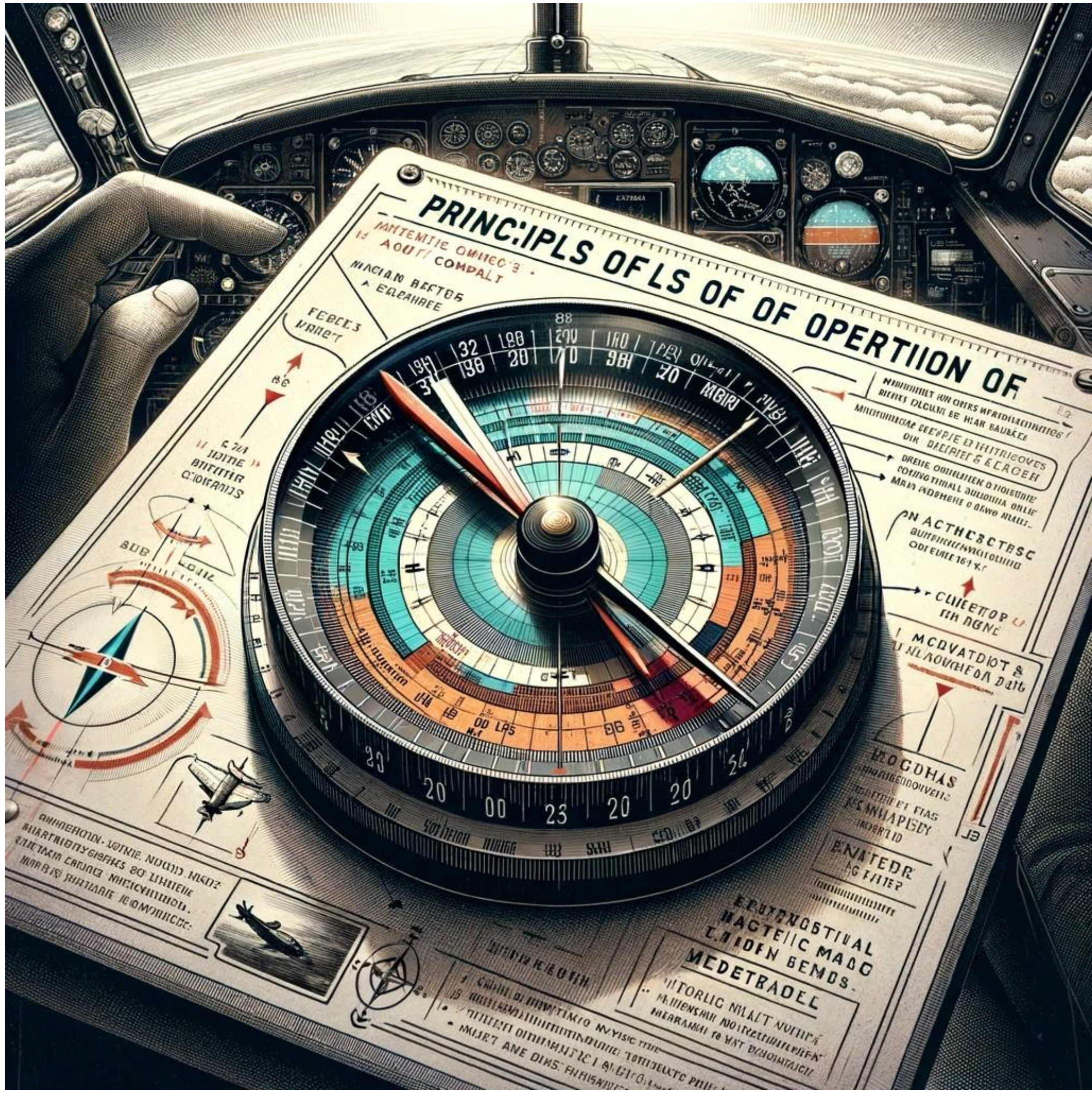
First Part :
Fundamental Challenges Of Implementing AI

What are fundamental challenges of implementing AI?



Principles

- **Non-overlapping.**
- **Not contradictory.**
- **Independent** of the size, complexity, staffing levels and nature of operations of the Air Navigation Service Organizations (**ANSPs**).
- **Address the European ATM** although most of them can be applied to other **ATM** systems worldwide.
- **Pragmatic** in nature.
- **Not connected** to a particular **AI/ML** paradigm to the extent possible.



Level – 1: Political / Regulatory

1. **Fragmentation** of the European **ATM**.
2. **Complexity** and novelty of **AI** related products certification.
3. Established safety assurance frameworks **are not adapted** to **AI/ ML** and development of the **Learning Assurance Concept**.
4. State **sovereignty** concerns.
5. **Legal differentiation** between Air Traffic Services Providers and **ATM** Data Service Providers.
6. Complexity of **agreements on risk sharing and charging mechanism** between States.
7. Definition, sharing, and applying a **common policy** on ethics, related to **AI**.
8. Maintain the credibility and reliability of the **ATM** systems by promoting **social acceptability** and change management.
9. Build the **trust** through a system of rules that distribute and clearly define the responsibilities and operating limits of the **AI** and the operator.

Level - 2: ANSP / Business

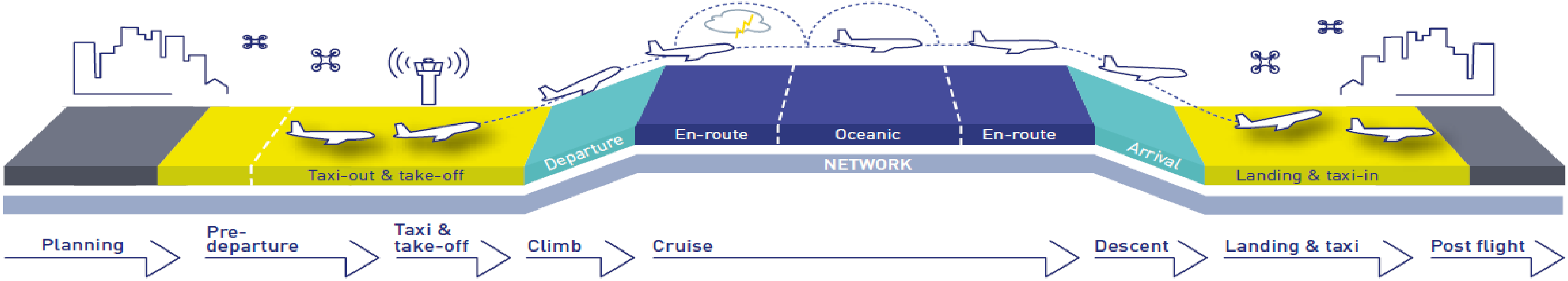
1. Organizational **transformation issues.**
2. **Insurance and liabilities.**
3. Constraints from the **early adoption** of new technology.
4. Unclear **cost-effectiveness** benefits.
5. Complexity of **service borders** and **scope definition**.
6. Costly reinforced **cybersecurity infrastructure**.
7. Complexity of **service continuity requirements**.
8. Disruption of established **knowledge sharing**, learning procedures, and practices within **ANSPs**.
9. Encourage **feedback paths from operators**, to be shared with systems developers.
10. Build a new **change management policy** to gradually drive operators through new technologies and working methods.

Level - 3 : Technical

1. **Complexity of sharing** of **AI** infrastructure between countries.
2. **Extreme dependency** of the **ML** models on the datasets that are used for training, validation, and testing.
3. **Curse of dimensionality**, which refers to the extraordinarily rapid growth of the complexity, as the number of variables (or dimensions) increases.
4. **Significant differentiation** of **AI** solutions for Tower, Approach and Area Control operations.
5. Tailor made **AI** solutions cannot be easily **generalize across** same type of units in different geographical areas.
6. **Consolidation of critical data** to guarantee consistency, integrity, and safety of displayed information on the Controllers' Working Positions.
7. Develop **backup systems** to face failures or unusual situations in complex **AI** systems.
8. Define effective **AI** methods to detect, frame into context, and interpret into decisions **weak signals**.

Level - 4 : Operational

1. A **scale shift in complexity** in terms of the density of interdependencies across processes and activities.
2. **Synchronization** of operational procedures between Air Traffic Services Units **(ATSUs)** and between **ATSUs** and Network Manager.
3. **Incompatibility with existing Concept of Operations (CONOPS)** and the need of development of new ones.
4. **Explainability** issues of the **ML** models.
5. **Function allocation issues**. Avoiding leftover strategy where the **ATCOs** are expected to assume control when automation fails.
6. Develop, validate and harmonize the **integration of AI technologies** in the whole system, among all users.
7. **Disruption of established relationships**, lines of communication and the ability to exert authority.



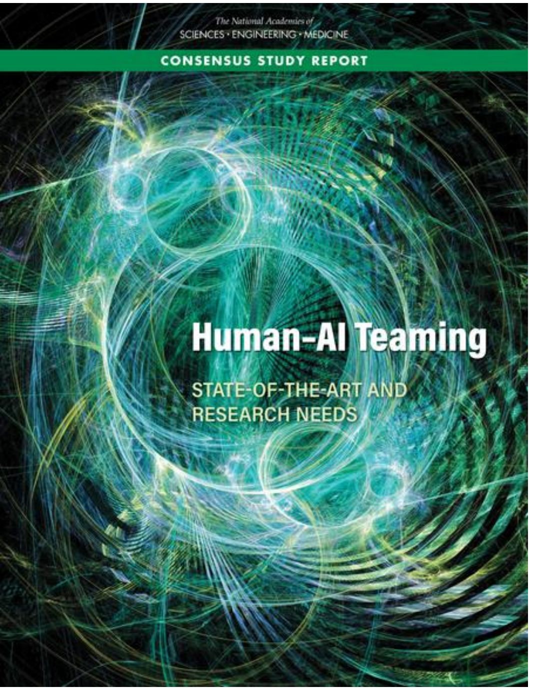
Level -5 : Air Traffic Controllers

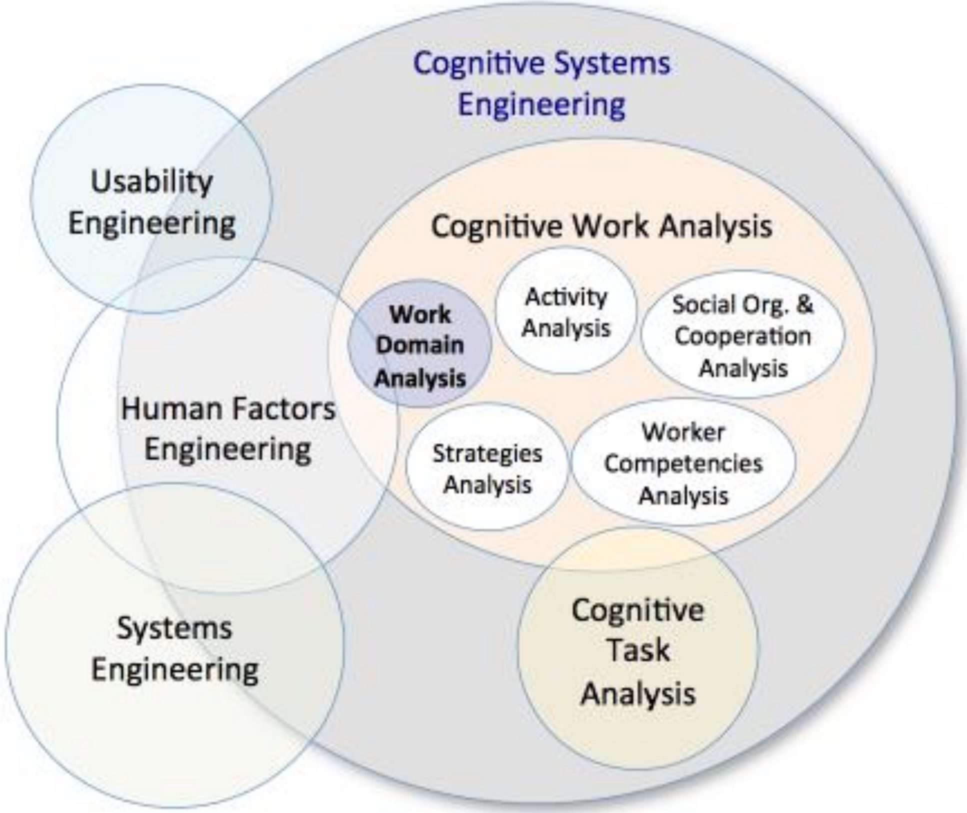
1. Keeping the ATCO 'in the loop' and situationally aware and able to intervene.
2. Disruption of established patterns in coordinated activity between ATCOs' and between ATCOs' and flight crews.
3. Disruption of established patterns of resilience.
4. Increasing instances of automation (AI/ML) surprises and clumsiness.
5. Increased space for potential and new type of errors that cannot be easily foreseen.
6. Demands for new kind of knowledge and skills.
7. Demands for more threads to track that makes attention management difficult.
8. Demand for the development of new mental models, how the AI system works, how it fails, why it fails, and how to adapt.
9. ATCOs acceptance of their new roles and remits.
10. Synchronizing an increased number of micro-cultures of ATCOs' communities which are based on their local practices and local affordances.
11. De-Skilling of ATCOs.
12. ATCOs' intervening during failures and contingencies, (Leftover strategies).
13. Vigilance / boredom tradeoffs.
14. Managing of social aspects (e.g., relocation and mobility of ATCOs).
15. Resistance from ATCOs' who could legitimately fear for their jobs.

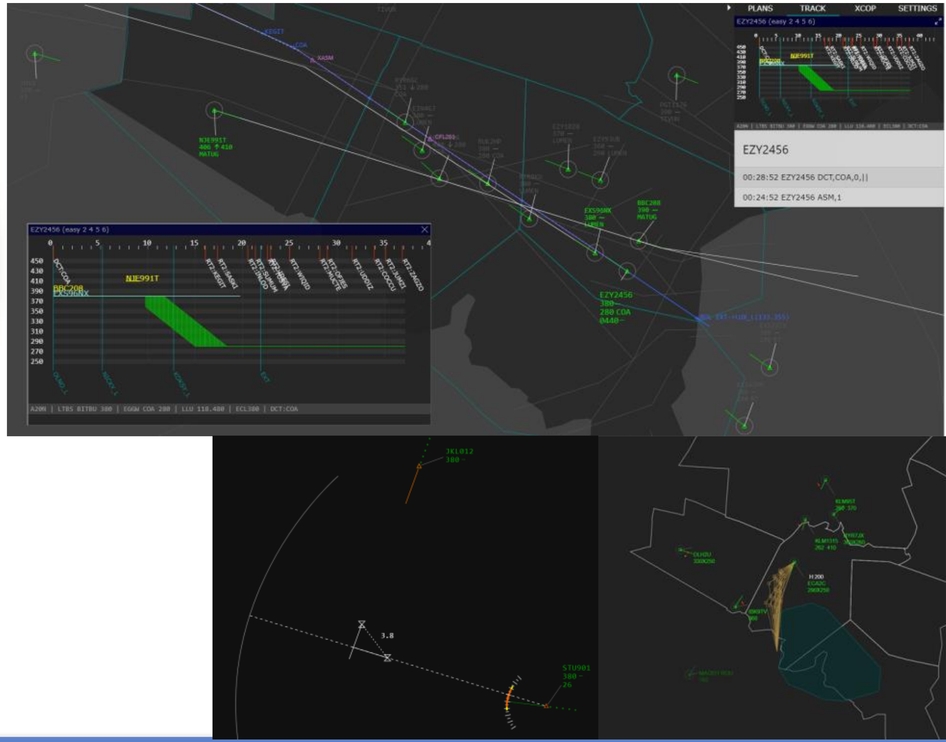
Second Part :
Human Machine Teaming

What was the Goal?

Develop a **Human Machine Teaming guide** for Air Traffic Controllers that can be used to support effectively **Adaptive Human - AI teaming**

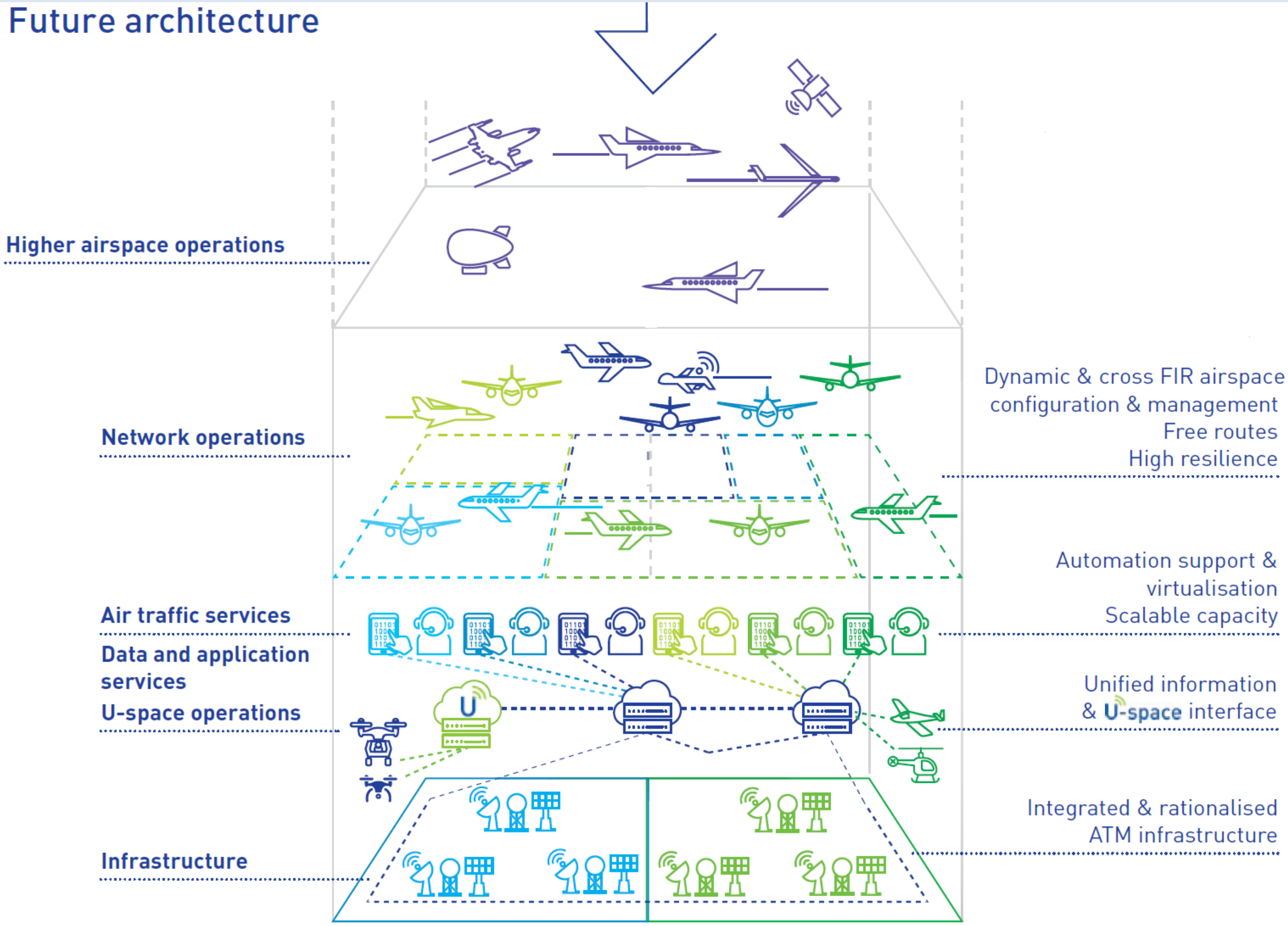




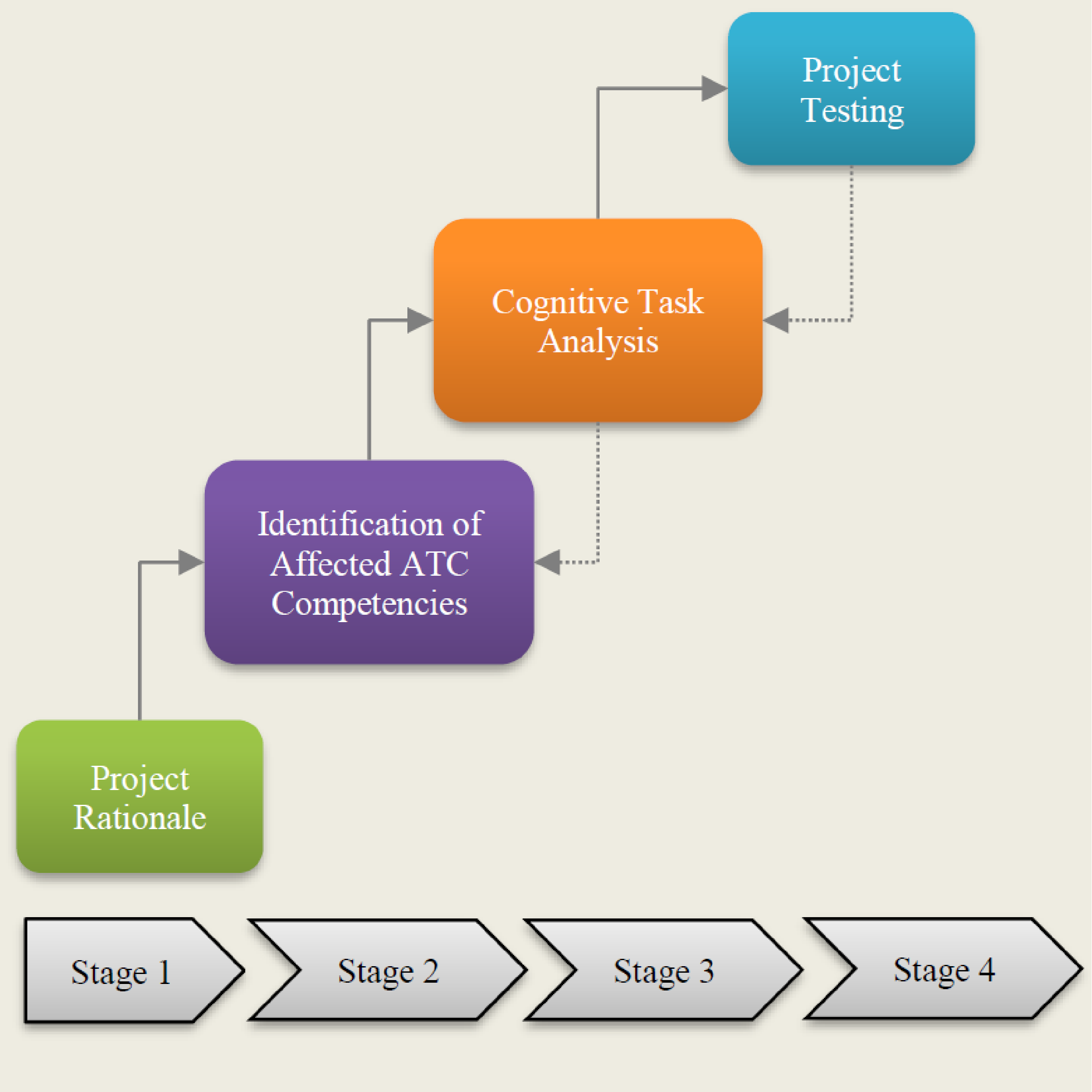


Future ATM architecture - (SESAR JU)

Future architecture



Human Machine Teaming process implementation steps

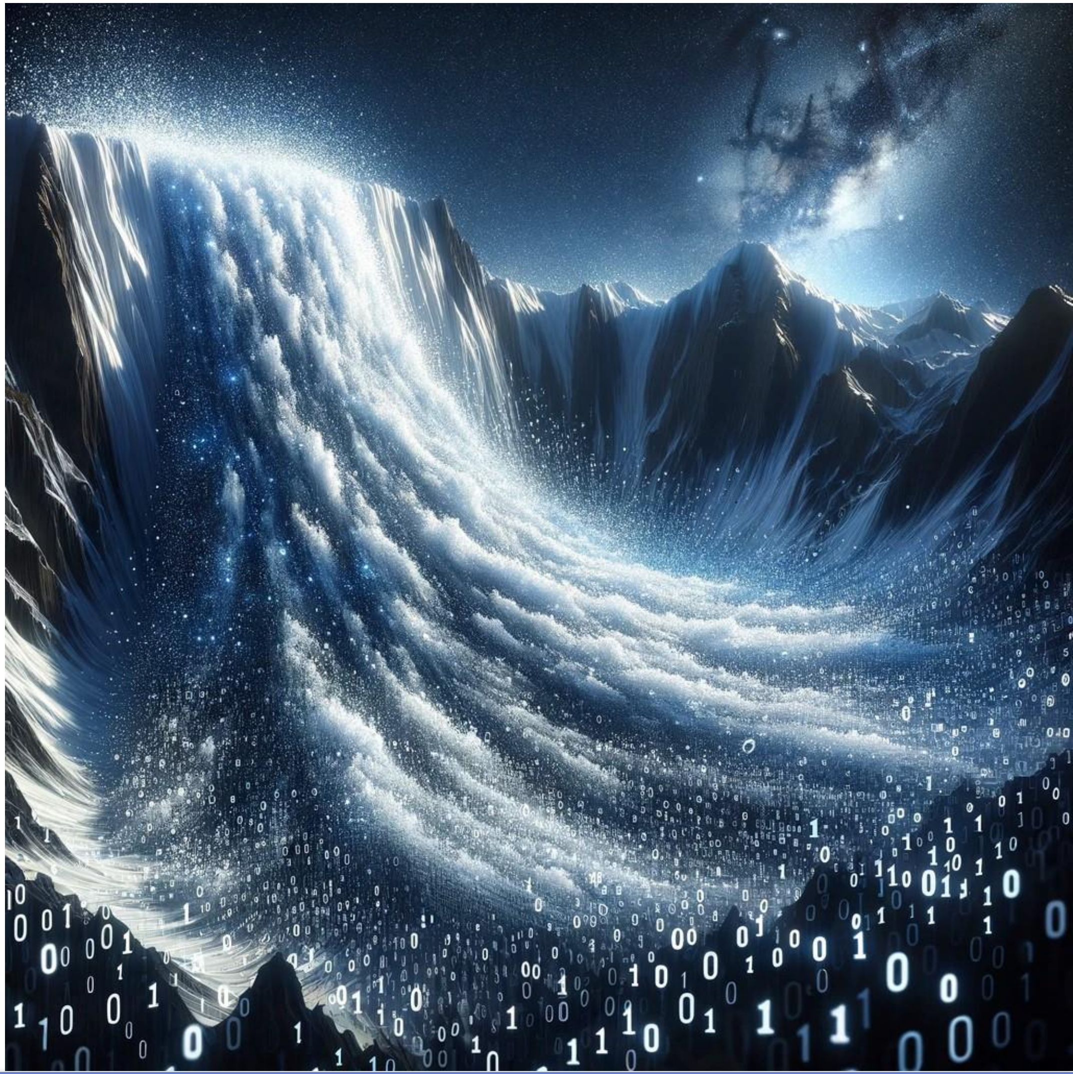


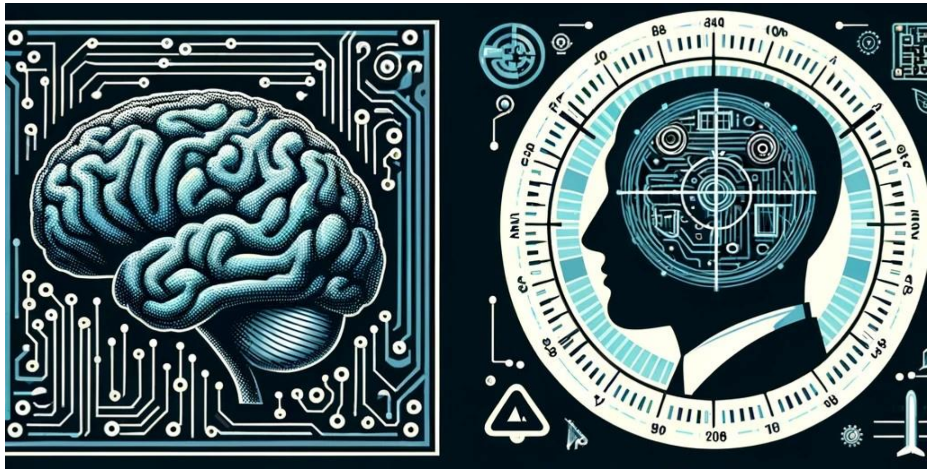
Generic Principles

1. Focus on designing and delivering **operator-centred technology**.
2. The trade-off between **augmentation and assistance** must be carefully balanced.
3. Aim for **a diverse set of use-case scenarios**.
4. Develop and utilize several **technology-specific** and **operational metrics**.
5. Design the technology with the capability to **monitor and update the system after deployment**.
6. Test the systems **in isolation** and **in cooperation** with the other affected systems.

AI/ML Specific Principles

1. **Data Sets (test, training, validation)** must be carefully selected, preserved, and utilized.
2. Understanding the **limitations of the datasets** and models used.
3. Design early the AI/ML model to be **interpretable**.





Identification of the affected ATC competencies

- Situational Awareness
- Traffic and Capacity Management
- Separation and Conflict Resolution
- Communication
- Coordination
- Management of Non routine Situations
- Problem Solving and Decision Making
- Self-Management and Continuous Development
- Workload Management
- Teamwork

Cognitive Task Analysis

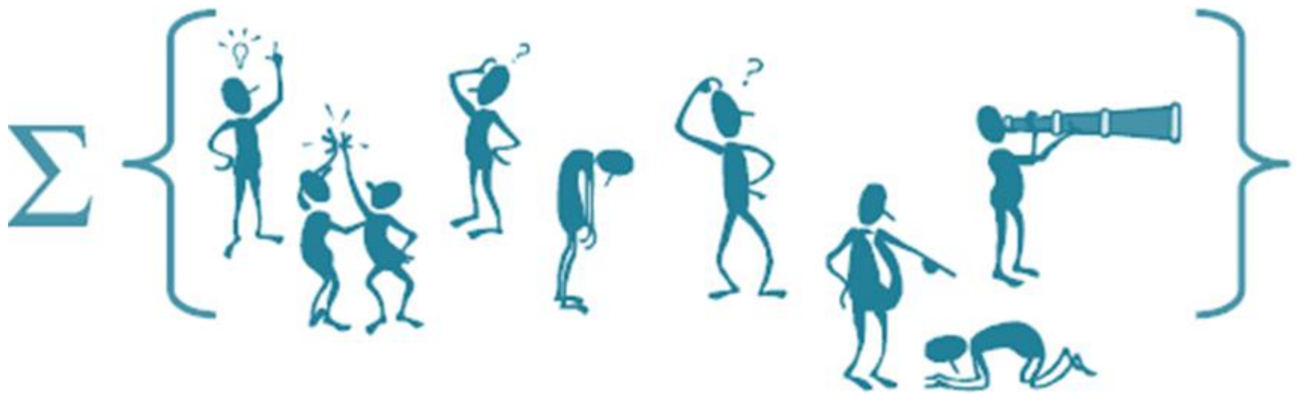
1. **(A)ssessment of the situation**—how ATCOs recognise similar situations experienced in the past and how they manage uncertainty to assess new situations.
2. **(B)alance of constraints and resources**—how ATCOs evaluate difficulties, threats, and constraints imposed by the situation as well as how they use resources and affordances provided in the operating environment *(affordance is the perception of what actions the environment offers).*
3. **(C)ommunication**—how ATCOs communicate information, intentions, and actions to others and how they coordinate with adjacent sectors.
4. **(D)ecision making and planning**—how ATCOs make decisions, how they work in smart ways and improvise, how side effects are prevented, and how plans may turn out differently.
5. **(E)rror detection and recovery**—how ATCOs make provisions to review their work progress, how they manage to detect errors, and later recover them in a timely fashion.

The way Forward

What does it now mean to be ‘in control’ in the era of AI?

How to amplify control within the new range of possibilities and technologies?

How can we support effectively Human AI teaming in the ATC Operation Rooms?



Questions