AI Situational Awareness Foundation for Advancing Automation — AISA

Concept of Operations Workshop

On-line meeting, 16 September 2020
Overview

Purpose of the Workshop:
• Present the AISA ConOps to stakeholders
• Gather feedback on ConOps
• Discussion about future work

Agenda:
• Presentation 45 minutes
• Q&A, discussion 45 minutes

Presentation:
• Future ConOps
• AISA Project
• AISA ConOps

Visit us at:
aisa-project.eu

Contact:
tradisic@fpz.unizg.hr
AISA project has received funding from the SESAR JU under grant agreement No 892618 under European Union's Horizon 2020 research and innovation programme.
This project addresses the call topic “Digitalisation and Automation principles for ATM”.

The framework for this project is to propose a solution which builds the foundation for successful cooperation between human and machine.

The scope of the project is to present a vision of automation in a specific ATM operational environment (en-route ATC) and address the challenges of transparency and generalization.
Future ConOps According to ATM Master Plan
Future ConOps

• Prepared according to ATM Master Plan and the SESAR ConOps

• Used here to ‘set the stage’ for AISA

• Concept of Operations explains more about ‘what?’ will be done

• AISA is more about ‘how?’ will things be done
**Future ConOps**

**FIGURE 16. TARGET ROLLOUT OF SESAR**

<table>
<thead>
<tr>
<th>Phase A</th>
<th>Adress known critical network performance deficiencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>SESAR solutions deployment</td>
<td>Phase B</td>
</tr>
<tr>
<td>SESAR solutions deployment</td>
<td>Phase C</td>
</tr>
<tr>
<td>SESAR solutions deployment</td>
<td>Phase D</td>
</tr>
</tbody>
</table>

| U-space deployment | U-space is deployed with shorter lifecycles. Technologies are deployed when mature |

<table>
<thead>
<tr>
<th>Years</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
<th>2035</th>
<th>2040</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option 1</td>
<td>[\text{R&amp;D}]</td>
<td>[\text{end of V3}]</td>
<td>[\text{start of deployment}]</td>
<td>[\text{full operational capability}]</td>
<td>[\text{standardisation and industrialisation}]</td>
<td></td>
</tr>
<tr>
<td>Option 2</td>
<td>[\text{R&amp;D}]</td>
<td>[\text{end of V3}]</td>
<td>[\text{start of deployment}]</td>
<td>[\text{full operational capability}]</td>
<td>[\text{standardisation and industrialisation}]</td>
<td></td>
</tr>
</tbody>
</table>

**European ATM Master Plan**
WP 2 – Concept of Operations (6)

AISA Concept of Operations Workshop

- **A** Address known critical network performance deficiencies
  - Introduction of common standards for deployment
  - Network Manager balances capacity and supports network tasks

- **B** Efficient services and infrastructure delivery
  - Cross-border Free Route & Operational excellence
  - Enabling framework for ATM Data Services and capacity on demand, First ADSP certified

- **C** Defragmentation of European skies through virtualisation
  - Network-wide dynamic airspace configurations
  - ATM Data Service Providers and Virtual centres providing capacity on demand

- **D** Digital European sky
  - Fully scalable services supported by a digital ecosystem minimising the environmental footprint of aviation

- **ANS/NM**
  - Implementation of target architecture and transformation to trajectory-based operations

- **Automation levels (air and ground)**
  - Advanced network operations and services
  - Integrated & rationalised ATM infrastructure
  - Automation level 2/3
  - Automation level 4/5
WP 2 – Concept of Operations (7)

LEVEL 2
TASK EXECUTION SUPPORT

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.

LEVEL 3
CONDITIONAL AUTOMATION

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.
Future ConOps – SESAR
Operational Key Features

Optimised ATM Network Services
- Optimised AU operations
- Advanced airspace management
- Advanced DCB

Advanced Air Traffic Services
- Advanced air traffic services and trajectory management
- Conflict management
- Enhanced arrival and departures

High Performing Airport Operations

Transversal Topics
- Trajectory-based Operations
- Free route operations

- SESAR ConOps
Future ConOps – En-route ATCO’s Tasks

• What will ATCOs tasks look like in 2035 and 2040/2050?
• Difficult to predict exactly, especially for 2040/2050 horizon
• Some tasks:
  • ...will be made obsolete
  • ...will be delegated to automation
  • ...will be supported by automation
  • ...will be new
Future ConOps – En-route ATCO’s Tasks

E.g. Conflict Management

Currently:
• Conflict detection - done by ATCO with support of CDT
• Conflict resolution - done by ATCO (EC)
• Conformance to the solution - done by ATCO (EC), supported by conformance monitoring tools
• Update aircraft’s plan - done by ATCO (EC)

SESAR ConOps for 2035:
• Strategic conflict detection and resolution – done by Network Manager via Reference Business Trajectory negotiation
• Early (medium- to long-term) conflict detection – done by Planner Controller (MSP or EAP) with support of MTCD tools and coordinated via Integrated Network Manager and Extended ATC Planner (INAP)
• Early conflict resolution – done by EC or PC of the upstream sector, supported by conflict resolution tools, accomplished via RBT negotiation, coordinated via INAP
• Tactical conflict detection – done by CDT, monitored by ATCO
• Tactical conflict resolution – proposed by CR tools, approved by ATCO, uploaded via CPDLC
• Conformance management – fully automated
Future ConOps – En-route ATCO’s Tasks

Future ATCO’s tasks:

- More automation/tools
- More integration
- More interdependencies
- More coordination
- Changing roles

Many hurdles along the way. One of them: How to make human and machine work together?
What do we want from AI/automation?

European Aviation/ATM industry and European Network operations shall rely on **Trustworthy Human Centric AI** solutions to:

- improve its operational performances and international competitiveness
- support the realization of recent EU initiatives focusing on aviation/ATM digitalization

Further exploration of the potential of AI in aviation/ATM should be strengthened in areas of:

- high impact on aviation/ATM performance and environment
- human-machine collaboration
- safety-critical operations
- safety intelligence tools and cyber threat intelligence services

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- European Aviation/ATM AI High Level Group
  FlyAI Report, 2020
# A small detour - AI Waves

<table>
<thead>
<tr>
<th></th>
<th>1st Wave</th>
<th>2nd Wave</th>
<th>Modern 2nd Wave</th>
<th>3rd Wave</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>When:</strong></td>
<td>1960s – 1980s</td>
<td>1980s – 2010s</td>
<td>2010s –</td>
<td>2020s –</td>
</tr>
<tr>
<td><strong>Technology:</strong></td>
<td>Expert Systems</td>
<td>Machine Learning</td>
<td>Deep Learning</td>
<td>?</td>
</tr>
<tr>
<td><strong>Algorithms:</strong></td>
<td>Logical Rules</td>
<td>Statistical Methods</td>
<td>Statistical Methods</td>
<td>? Hybrid Methods</td>
</tr>
<tr>
<td><strong>Learning:</strong></td>
<td>Difficult</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td><strong>Uncertainty:</strong></td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td><strong>Explainable:</strong></td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td><strong>Data Needs:</strong></td>
<td>Modest</td>
<td>Large</td>
<td>Huge</td>
<td>Modest</td>
</tr>
</tbody>
</table>

Adapted from Jésus García
Desirable Traits of AI/Automation

- Safety
- Efficiency
- Collaboration
- Coordination
- Complementarity
- Explainability
- Small data needs

Avoid:
- Deskilling
- Annoyance
- OOTL
- Complacency

Some of these goals can be achieved by human and machine sharing the situational awareness
AI Situational Awareness Foundation for Advancing Automation — AISA
AISA Objectives

Overall objective:
• Increase the possibility for introduction of automation in air traffic management (ATM) by researching domain-specific application of transparent and generalizable artificial intelligence methods.

Specific objectives:
• Explore the effects of human-machine distributed situational awareness and opportunities for automation of monitoring tasks in en-route operations.
• Identify the data needed by air traffic controller (ATCO) to ensure that the proposed solution is correct (transparency) and develop the method to provide that data (explainability).
• Investigate methods for adaptation of the automated system to changes of the environment ensuring business continuity and safety.
AISA – Project Positioning

Current
- Pre-TRL1
- Scientific research

Planned
- TRL1
- Basic principles observed and reported

Ambition
- TRL2
- Technology concept and/or application formulated
Situational awareness or situation awareness (SA) is the perception of environmental elements and events with respect to time or space, the comprehension of their meaning, and the projection of their future status.

- Endsley

Artificial Situational Awareness as a Foundation for Further Automation
Our assumptions are:

- Ideally, TSA represents the complete situation with all interactions among aircraft, humans and systems, including accurate representation of system and human states.
- Essential component of TSA is the ability to project future states from current ones.
- A single actor (machine or human) does not have to have complete SA; in this way SA is only partial for each actor.
- Individual SA should overlap to the extent that makes the operations safe and practicable.
- TSA should be distributed among actors in a way that favors individual strengths.
AISA Architecture

ATCO Team

Controller Working Position

Interactive Data Presentation and Explanation

Query Scheduler

Reasoning Engine

ATC Knowledge Graph

Rule-based Knowledge

Data Translators

Aeronautical Data

Traffic Situation

ML/DL Modules

Other Tools
Aware of What?

AISA should be aware of:

- the traffic situation
- its own (system’s) state
- other team member’s states

Caveat: Significant difference between AISA project goals and envisioned application of AISA in 2035 or 2040/2050
Awareness of the Traffic Situation

Benefits

- Additional Safety Net
- Attention Guiding
- Informing/Alerting
- Proposing Solutions

Automation of Monitoring Tasks

- Situation-dependent Activation of Tools/Modules
- Prioritization/Arbitration Among Tools/Modules

Central Coordination of Tools/Modules

- Identification of Missing Information
- Obtaining Missing Information via CPDLC or SWIM
- Automated Activation of ML-based Tools
- Situation-dependent Information Presentation

Automation of Gathering Missing Information

- Event-based Reporting for All Types of Traffic Events
- In-depth Semantics-Based Statistics

Automated Reporting
## Conflict Management example

<table>
<thead>
<tr>
<th>Task</th>
<th>Actor</th>
<th>Method</th>
<th>Potential role of AISA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategic CD&amp;R</td>
<td>NM</td>
<td>RBT negotiation</td>
<td></td>
</tr>
<tr>
<td>Early conflict detection</td>
<td>Planner Controller (MSP or EAP)</td>
<td>Supported by MTCD tools and coordinated via INAP</td>
<td>Checking plausibility of MTCD results, checking for missing data needed for optimal tool operation</td>
</tr>
<tr>
<td>Early conflict resolution</td>
<td>EC or PC of the upstream sector</td>
<td>Supported by CR tools, accomplished via RBT negotiation, coordinated via INAP</td>
<td>Providing explanation of the effects of the proposed solution, checking plausibility of the solution</td>
</tr>
<tr>
<td>Tactical conflict detection</td>
<td>System (CDT), monitored by ATCO</td>
<td>CDT</td>
<td>Autonomous activation of the CDT tool, timely informing ATCO, alerting ATCO if conflict is overlooked, filtering relevant traffic</td>
</tr>
<tr>
<td>Tactical conflict resolution</td>
<td>Approved by ATCO</td>
<td>Proposed by CR tools, uploaded via CPDLC</td>
<td>Plausibility check, checking the effect of CR results on other traffic</td>
</tr>
<tr>
<td>Conformance management</td>
<td>System</td>
<td>Comparison of actual trajectory to RBT</td>
<td>Checking adherence to closed-loop clearances, reminding ATCO of open-loop clearances</td>
</tr>
</tbody>
</table>
Awareness of the System State

➢ Checking ML/DL modules:
  • ML/DL modules are ‘black-boxes’
  • Monitoring inputs to check if the ML/DL module was trained on such data
  • Monitoring ML/DL outputs to check the plausibility of the results
  • Monitoring ML/DL module’s performance (e.g. accuracy)

➢ Monitoring status of other ATCO tools

➢ Self-monitoring:
  • Checking for missing data
  • Checking own performance (e.g. query execution time)
Awareness of Team Member’s State

- Difficult to do right
- Educated guessing

Some possibilities:
- Workload can be inferred based on the traffic complexity
- Complexity can be estimated by ML systems trained for complexity assessment
- Activation or near-activation of safety nets can be a sign of overload or OOTL effect
- Ignoring system’s suggestions can be a sign of annoyance
Contribution to the Call Expected Impacts

‘Projects are expected to provide principles that could enable higher levels of automation that are predicted to lead to an improvement of ATM performance, in particular cost efficiency, capacity and safety’

- Call Technical Specification

✓ positive effects on safety – AISA introduces an additional safety net
✓ positive effects on capacity – AISA takes over some of the ATCO’s monitoring tasks thus reducing workload
✓ other performance areas – AISA enables other automation technologies

Overall positive impacts can be expected in the society due to reduced costs of air traffic which can improve mobility and economic growth.
Thank You!

AI Situational Awareness Foundation for Advancing Automation (AISA)