Quantitative prediction of automation effects on ATCo Human Performance

Patricia López de Frutos (CRIDA)
pmldefrutos@e-crida.enaire.es

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Acknowledgement

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AUTOPACE responds to the first Call for Proposals of SESAR Exploratory Research projects launched under Horizon 2020 Research Framework Programme.

Particularly AUTOPACE addresses the Research Topic:

• ER-01-2015: Automation in ATM with the aim of increasing the awareness of the interaction between automation and human performance.

T0 March 1st, 2016 – 2 years duration –ALREADY CLOSED
Need for Research

Automation will unavoidably change the ATCo work environment

2050 Timeframe – HIGHLY AUTOMATED ENVIRONMENTS

Performance drawbacks “out of the loop” effect or fears of automation failure

Role of the ATCo will move towards tasks focused on monitoring and supervision of the system
Research Path

ATCo Psychological Model

- Better understanding on how cognition and automation live together
- Support new training strategies for future ATCo
- Quantify how automation impact on ATCo performance
ATCo Psychological Model

Representation of the ATCo human cognitive system to facilitate investigation
ATCo Psychological Model
Two Components

Mental Resources
Energy needed for the functioning of Cognitive processes

Cognitive Structure
Processing of traffic situation and Operational environment

Traffic situation
Operational environment
Cognitive Structure for an ATCo
Histon & Hassman (2008)
Mental Resources
Gopher, D. and Donchin, E (1986)

Cognitive Processes requires energy

Demanded Resources

Available Resources

Task Complexity

Level of Activation

Mental Workload

Gopher, D. and Donchin, E (1986)
How do we analyse the impact of automation on ATCo MWL?

- Psychological Model
- Computational Model
What is COMETA?

COMETA is a prototype developed by CRIDA to estimate ATCo cognitive demand in en-route phase flexible to new concept of operations.

COMETA is based on Multiple Resource Theory (Wickens y McCarley, 2008) to quantify cognitive demand.

COMETA incorporates functions to dynamically model the continuous monitoring based on flights in evolution, standard flows, flights out of standard flows and potential crossings.
COMETA Prototype coverage

Demanded Resources

Available Resources

Task Complexity

Level of Activation

Mental Workload

Currently assumed as a constant value. To be developed in further research.
COMETA Inputs and Outputs

Traffic and Environment

ATC Event Generator

ATC Events

ATCo Task Model

COMETA (Cognitive Demand Calculator)

Demanded Resources
ATCO Event Generator

- Traffic
- Environment
- Operational Procedures

Fast Time Simulator (RAMS)

- Conflict Detection and Resolution Modelling
- ATCo Events Modelling

ATCo Events
ATCo Task Model

Plan a traffic exit & release a traffic

Prior

Analyse traffic exit

SEC

Decide about exit conditions

ATCo Event

ATCo Actions

ATCo Behavioural Primitives & Mental Resources
COMETA Calculator (Wickens y McCarley, 2008)

When tasks overlap in time, the demanded resources depend on

\[
\text{Demanded resources} = \sum_{c=1}^{u} w_c + \sum_{c=1}^{N} \sum_{d=c+1}^{N} i^{(c,d)}
\]

\(w_c\) = resources demanded by channel: perception (visual, auditory), comprehension, projection, decision-making, respond (manual or verbal)
\(i^{(c,d)}\) = interference between channels \(c\) and \(d\)

The resources for processing each cognitive process

If the two tasks use the same pool of resources there will be interferences that increase the demanded resources.

The interference could be modified by the prioritization of tasks.
COMETA Outputs

Cognitive Demand

Cognitive Process Distribution

ATCo Events

ATCo Actions
Highly Automated Environments: Concept of Operation and Scenarios for 2050
Methodology for 2050 CONOPS Definition

2035 AUTOPACE ConOps definition
- Literature research on SESAR Documents
- AUTOPACE requirements (execution phase, en-route environment, ATC perspective)

2050 AUTOPACE ConOps definition
- Literature research Flightpath 2050 Vision, ACARE, EREA, and HALA! Position Paper

AUTOPACE scenarios identification and description
- Automation Scenarios
- Non-nominal situations
- ATCo Responsibilities
2050 AUTOPACE ConOps

In a nutshell

Air Traffic Forecast

- Forecast is characterised by moderate economic growth: 18.6 million IFR movements in Europe by 2050 (2 times more than in 2012 and 1.3 times more than in 2035)

Airspace Management

- Trajectories are de-conflicted and free-route is in place
- Sectors bigger than current sectors;
- Flight Centric: Several ATCo will be operating in the same sector

4D Contract

- The aircraft are in charge of executing their contracts and the ground system monitors them
## AUTOPACE Scenarios - Horizon 2050

### ATCo Responsibilities

<table>
<thead>
<tr>
<th>Apply</th>
<th>Approve</th>
<th>Monitor</th>
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<tbody>
<tr>
<td>• System <strong>proposes solutions</strong>&lt;br&gt;• ATCo decides and selects most suitable solution before implementation</td>
<td>• System <strong>proposes a solution</strong>&lt;br&gt;• ATCo approves before implementation</td>
<td>• System assumes major tactical actions&lt;br&gt;• ATCo monitors its behaviour to prevent system deviations</td>
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### ATCo Automation Levels

- **Medium Automation**
- **High Automation**
Examples of ATCo Responsibilities

<table>
<thead>
<tr>
<th>ATCo Responsibilities</th>
<th>Medium Automation</th>
<th>High Automation</th>
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</thead>
<tbody>
<tr>
<td>Provide early conflict detection and resolution</td>
<td>Approve</td>
<td>Monitor</td>
</tr>
<tr>
<td>Assign specified headings, speeds and levels</td>
<td>Approve</td>
<td>Monitor</td>
</tr>
<tr>
<td>Provide flight information to all known flights</td>
<td>Monitor</td>
<td>Monitor</td>
</tr>
<tr>
<td>Determine the needs for Complexity Solution Measures</td>
<td>Apply</td>
<td>Approve</td>
</tr>
<tr>
<td>Provide Alerting Services</td>
<td>Monitor</td>
<td>Monitor</td>
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No Nominal Situations

Conflict Detection and Resolution System Failure
- ATCo will have to search for conflicts each time an aircraft is entering his/her area of responsibility and solve them.

Complexity Management System Failure
- De-complexing measures not applied.

System Supported Coordination Tool Failure
- No automatic coordination and former procedures are required.
Modeling Highly Automated Scenarios in RAMS+COMETA
Scenarios in RAMS

- **Concept of Operation**
  - **De-Conflicted**
  - **Free-Route +Flight Centric**

- **High Automation**
  - **Conflict Detection And Resolution System fail**
  - **Complexity management system fail**
  - **Communications support system fail**

- **Medium Automation**
  - **2015**
  - **2050**

- **Baseline**
  - **Reference**

- **2015**
  - **2050**

- **Traffic**
ATCo Task Model: Events, Actions, Behavioural Primitives

ATCo Actions in **HIGH** AUTOMATION
- Evaluate tactical conflict between traffics
- Monitor the tactical conflict resolution applied by the system

ATCo Actions in **MEDIUM** AUTOMATION
- Evaluate tactical conflict between traffics
- Evaluate the proposed solutions to conflict
- Decide the tactical conflict resolution from the proposed ones

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Results
Nominal Situations - Occupancy and Mental WL

- The MWL in average (arithmetic mean) is similar (dotted lines) in MA and HA.
- The standard deviation (coloured bands) is smaller in HA than in MA Scenario showing a more stable behaviour (more robustness to variations of occupancy).
- In HA the ATCo is mostly supervising and monitoring the system. In MA, “approving” and “applying” actions are also in place and hence, the ATCo is performing more diversity of tasks that imply more variability in terms of MWL.
Distribution of the cognitive processes demand

Current ATCo uses the cognitive dimensions in a balanced way.

Future ATCo shall focus his/her cognitive effort in mainly comprehension and projection. The ATCo needs a good SA to check the system performance.
No Nominal Situations

High Automation

- In HA Scenarios, Conflict resolution failure could be declared as unsafe, not being possible to be assumed by the ATCo

Medium Automation

- In MA Scenarios, the MWL distributions are not so far from nominal situations as in HA Scenarios since the ATCo activities do not change so drastically. Mitigation actions should be put in place to make situations affordable and safe
Conclusions and Further Research
Further Research (1/2)

The computerization of the psychological model would provide a powerful tool to quantify the benefits and weaknesses of different levels of automation on the cognitive processes.

COMETA is still a prototype and further research is needed to incorporate the ATCo level of activation model and therefore the quantification of available resources.
Further Research (2/2)

MWL quantification would also support quantification in terms of Airspace Capacity and Cost-Efficiency (ATCo productivity).

The benefits of the training and its effect on ATCo MWL could be tested with the abovementioned computational model to see the most promising training plan.
Thank you very much for your attention!