The Effect of a Highly Automated Environment on Human Behaviour

Plans and first results of the WP-E project "ADAHR"

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Foreword **- This paper describes a project that is part of SESAR Work package E, which is addressing long-term and innovative research. The project was started early 2011 so this description is limited to an outline of the project objectives augmented by some early findings**

Abstract **- This paper describes the ADAHR project which evaluates the impact of high levels of automation (LoA) in future operational environments (2020-2050) on human factors aspects, like roles and responsibilities, interactions and situation awareness. The assessments are done by means of Gaming Sessions which are essentially human-in-the-loop activities, but they are especially suitable for concepts where the decision-making processes of several actors are a key factor. A set of scenarios addressing different automation levels will be defined for two environments: "Airspace Organization and Management" and "Airport Operations Centre". These scenarios will be simulated with several actors on one "Paper Based" platform and two different "Hardware Based" platforms. As an outcome of the ADAHR project a better definition and understanding of the different roles and responsibilities in a highly automated environment for the timeframe 2020-2035 will be obtained.**

Keywords – Automation, ATM, evolution, human role

I. INTRODUCTION

A major issue in Air Traffic Management (ATM) is the impact of the automation and new technologies on the human operator. Automated systems must be compatible with human capabilities. Development of effective and usable automated ATM systems requires Human Factors input throughout the design life cycle, from concept formulation, through detailed design, to implementation and operation.

Because of the importance of the coming changes of the future ATM system and its effect on human behaviour, now and in the far future, many European projects have focused their efforts on the evolution of human roles [1, 2, 3, 4]. Not surprisingly, one of the key focuses of SESAR is the role of the human and their relation with advanced automation tools to work safely, with an appropriate workload and with a high level of situation awareness.

Examples of long-running research in Human Factors issues are EUROCONTROL's HIFA (Human Factors Integration in Future ATM systems) and SHAPE (Solutions for Human-Automation Partnerships in European ATM) projects. HIFA [5] consist in both a database of human factor design guidelines and a tool for helping designers and project managers to consider application of human factors in the design of future Air Traffic Management Systems. SHAPE [6] deals with Human Factor issues raised by the increasing automation in European ATM.

Other examples are the European Commission projects in which the integration of Human Factors and (automated) aviation systems were assessed are HILAS (Human Integration into the Lifecycle of Aviation Systems) [7] and Episode-3 [8]. The latter was pioneer in the use of new validation techniques (such as Gaming Sessions) for assessing the human behaviour in complex environments.

The necessary level of automation for 2020 in a SESAR environment will be studied in the SJU programme, but this level of automation will be higher in the ATM environment after SESAR. There is some knowledge regarding how automation impacts on the workload and on the performance of an actor, but there is little knowledge regarding how the same automation impacts on the interactions and situation awareness among several actors with different interests (e.g. airspace users and Air Navigation Service Providers - ANSPs). Experience (e.g. automation in cockpit) has shown that the transition to higher levels of automation has to be carefully addressed to promote the trust in the new system, (guarantying certain safety levels), and to ensure its acceptability by the human operator. The ADAHR project, which is presented in this paper, will be focused on the impact of these high levels of automation on the human roles, with a time horizon ranging from 2020 to approximately 2050.

II. Presentation of the Project

A. Objectives

The basic research questions that are addressed by ADAHR are:

- How do different levels of automation in ATM impact the interaction between human actors?
- How does automation impact the roles and responsibilities of human operators in different environments?
- Which automation functionalities can be brought forward in the ATM master plan (post-SESAR)?
- What requirements on the implementation and change management are needed to promote the acceptance of higher levels of automation in the ATM environment?

Based on these research questions, the main objective of ADAHR is to assess the behaviour of different ATM human actors in a highly automated environment. This objective will be achieved through the:

- Identification of mechanisms that enhance the trust of the human actors in automation.
- Analysis of the impact of automation in the interaction between human actors.
- Analysis of the impact of automation on the new roles and responsibilities foreseen by the levels of automation addressed, especially in terms on workload and situational awareness.
- Analysis of the concepts/tools proposed to support ATM human actors and which will have a high LoA.

These objectives will be studied in two different environments:

- Airspace Organization and Management;
- Airport Operation Centre (APOC).

B. Approach

Starting from the SESAR definitions of human roles in 2020 and the expected technical capabilities of automation, new levels of automation will be assumed and new roles and responsibilities of human operators will be defined, for both environments. This work has already been carried out, and the results are described in section III of this paper.

Next, the scenarios will be defined for the two different environments and for two future automation levels (corresponding to a situation around approximately 2035 and 2050).

Then the impact of the automation described in the scenarios on human roles will be assessed. This will be done using the Gaming Technique, which has proven to be very suitable for this kind of assessments [8, 9, 10], and which is briefly described in section IV of this paper. This phase of the project will include the update of the gaming platforms where required, the design and the execution of the exercises.

Finally, the results will be analysed, compared to the initial objectives and the conclusions and recommendations will be drawn up.

C. Expected Results

The main expected result of ADAHR is a description of the expected roles of human operators in a highly automated ATM environment and a better understanding of the human interactions in those highly automated environments. Further expected results of ADAHR are:

- A first insight on the changes in stakeholder's strategies according to the level of automation.
- Exploration of the benefits of the introduction of higher automation levels in the ATM environment.
- Identification and pre-specification of tool's functionalities that support the introduction of higher automation levels.

III. First Results: Future Roles and Responsibilities

The first step of the scenario definitions was the descriptions of the roles of ATM actors that were likely to change significantly in the future due to SESAR induced changes. The process of how these roles were selected, and the factors that influenced this process, are given in the following sub-sections.

A. Actors and Roles in 2020

This sub-section describes the ATM actors and roles as expected to be in effect in 2020. The described actors are based on SESAR Definition Phase deliverables [11, 12, 13] and the SJU WP-B description of the Roles and Responsibilities related to Concept Storyboard Step 1 [14].

The actors and their roles are classified following ATM Components / Operational Services resulting in five categories [11, 12, 14]:

- Airspace Users;
- Airport Operators;
- Airspace Organization and Management;
- Air Traffic Flow and Capacity Management;
- Air Traffic Services Operations.

For each of these ATM Components, the roles & responsibilities and their interactions with other actors are described. It was also indicated how relevant/interesting the actor / role is for each of the two operational environments to be assessed within ADAHR project, based on the likelihood / expectation that the role would change significantly over time.

B. *Future Environment Description*

The main criteria used to determine whether a role description is expected to change in the future was based on studies dedicated to analyzing the future air transportation system of 2050 [1, 2, 3, 4]. The results of these studies were translated into so-called Levels of Automation (LoA). In literature, there are several taxonomies of LoA, from which the most broadly applied are those defined by Endsley and Kaber [15], Parasuraman et al. [16] and Parasuraman and Wickens [17]. For the ADAHR project the LoA taxonomy from Endsley and Kaber [15] was selected because its level of detail in the taxonomy makes it easier to categorize a new technology on the ten-point scale. It also pays attention to the (measurable) effects on the operator like measuring its human/system performance, situation awareness and workload. Finally, it allows a numerical classification and as such a comparison between studies, whereas the scheme of Parasuraman is a graphical visualization of the LoAs.

The different levels of automation correspond to how much freedom computerized tools get to make decisions, or how many decisions that nowadays are made by humans, will be made by computers in the future. For SESAR roles it is of great relevance to understand how LoAs will change over time. When the LoA increases, the risk exists that automation will be in control over so many tasks and issues that the ATM actor may get under-stimulated and out-of-the-loop. The technical feasibility to reach these higher LoAs, plus how operators will deal with the LoAs, are key issues for ADAHR to study.

The remainder of this section describes in terms of the foreseen development of LoA for both environments studied in ADAHR the expected future of aviation around three approximate points in time: 2020, 2035 and 2050. Although presented as a general increase of LoA with time, it is expected that there will be different levels of automation present in a system at any point in time.

It should be noted that the studies dedicated to analyzing the future air transportation system of 2050 tend to focus on how to deal with the environmental and fuel resource scarcity issues and less so on operational concepts and roles and responsibilities. Therefore the estimations and expectations about the future situation expressed in this paper are those of the ADAHR project team (unless stated otherwise).

1) *The Airspace Organization and Management environment*

a) *Stage 1 around 2020*

4D trajectories will be facilitated by ATC. Several tools will be available to support the Air Traffic Controller (ATCo) with that. Aircraft sequencing will become automated. ATC will get access to Conflict Detection and Resolution Systems and Arrival Management systems. The ATCo can still decide what solution (s)he prefers. More datalink will be used. Teams will change and one planner will support several executives.

b) *Stage 2 around 2035*

In the second stage, airspace will be used in a more flexible manner. For example, civil and military aviation will use the same airspace more often at the same time or after each other. Also, unmanned aircraft (e.g. cargo flights) may be introduced in civil airspace. As a result, people on the ground (ATCos, multi sector planners etc.) need to become more flexible in how they respond to traffic demands.

Conflict detection will be automated; it will detect and highlight potential conflicts in an earlier stage than a controller can. Most communication takes place through data link as all aircraft are expected to have data link facilities. Voice may still be used for non-standard communication.

Controllers will have more traffic under control, but most instructions to aircraft are provided automatically. However, the sizes of sectors can be stretched, which requires the controller to maintain conflict resolution and vectoring skills.

c) *Stage 3 around 2050*

The integration of the ATM systems is worldwide. The prediction of the routes and the routes in execution will be very reliable with a negligible margin of error.

There will be more uncontrolled airspace. Controllers will primarily monitor and coordinate the flow of aircraft in controlled airspace.

ATC has the possibility to scale up and down, between the levels of automation and the size of sectors. It still allows controllers to maintain their conflict resolution and vectoring skills. ATC can also be executed remotely: a controller might even work from home.

d) *LoA*

Foreseen software tools that might directly influence the roles of air management staff are:

- Automation that will better predict the take-off (and “airport ready for landing”) times.
- Automation that will enable sequencing of aircraft (in one ‘train’)
- Automation that will enable conflict free aviation in non-controlled airspace
- Data link can be used for communication between flight crew and ground.
- Network tools to modify the airspace in the short time.

The different LoAs of these tools will evolve gradually over time, which is described in detail in [18]. As a consequence of increased levels of automation:

- Controllers and Multi Sector Planners (MSP) may be able to serve more aircraft and/or larger sectors and airspace managers may be able to reduce their efforts responding to unexpected events.

- The roles of planner and executive controller may be integrated into one controller role and the airspace designer and manager can be merged to one unique role;
- Controllers will be increasingly responsible for the efficiency whereas the automation carries responsibility for the safety of the operation.
- Controllers may be able to work from home, which will have an impact on e.g. teamwork.

2) The APOC environment

a) Stage 1 around 2020

The APOC works collaboratively with all relevant stakeholders. It has a number of facilities / tools (diagnosis tools, what-if analysis, and decision support) to identify possible operational scenario(s) and to determine the impact of the scenario(s)

Each stakeholder makes the necessary changes within its own sphere of influence and responsibility and updates the Airport Operations Plan (AOP).

The Airport Monitor is an inseparable service of the AOP concept. It combines a process monitoring approach by integrating three sub-monitors (aircraft, passenger and baggage) and a performance approach by monitoring the Key Performance Indicators (KPI). To complete the airport "vision" additional information is also included such as weather forecast.

At around 2020 the APOC will serve as a communication, planning and organization platform to optimize airport processes. Representatives of all stakeholders at an airport will take part in, focusing on the next future.

b) Stage 2 around 2035

The decision support aspects of the APOC process in general will become more automated. Stakeholders will provide ranked alternatives to their initial plans to the Airport Monitor.

Because of increasing quality of automation the agents might not need to negotiate and adapt parameters as often as in 2020 to fit changes.

The improvement of technology for surveillance of aircraft and vehicles on the ground might help increasing the level of automation so that probably aircraft on the ground are not steered by pilots anymore, but automatically.

c) Stage 3 around 2050

In the third stage, airports will become more integrated with other modes of transportation, thereby coordinating the arrivals and departures of aircraft with arrivals of land and/or sea based connecting transports. This will require the integration of the passenger data, not just between connecting flights, but between transportation modes. The balance of competing stakeholder interests will become a major hurdle and will require powerful decision support tools. Agents might only monitor planning results and come only together in situations the system is not able to handle the situation anymore.

d) LoA

In 2020 with the help of a pre-tactical planning system, target times of airport ground processes are calculated. This software supports what-if functionalities and the manual input of changed parameters. The system proposes plans which need to be adapted or approved by the agents in the APOC.

When going to 2035 and 2050 it can be expected that the planning becomes more realistic and stable. Automation of aircraft ground movements and turnaround processes will be implemented. Agents might not need to adapt or approve calculated plans in daily operations anymore.

Consequently, the staffing of the APOC will be more and more limited. Stakeholders will communicate and coordinate, update, maintain and execute the agreed plan within their own respective area of responsibility.

3) Comparison of the two environments

Comparing the expected developments in LoA for the two environments the above descriptions might suggest that the future APOC environment will be more automated than the future Airspace Organization and Management environment. Although the increase in automation will be more in the APOC environment – simply because the current LoA is lower than that of the Airspace Organization and Management – the eventual LoA is expected to be lower because the APOC environment has more stakeholders with different/competing interests involved, which causes a greater need for coordination and cooperation.

C. Future Role Description

The study above resulted in a description of how the following roles will develop over the given time period, expressed in terms of task description, interaction with other roles and the expected impact of the changing role:

1) Airspace Organization and Management Environment

- Multi Sector Planner
- Executive and Planner controller
- Airspace Manager
- Local Traffic Manager

2) APOC Environment

- Airport Duty officer
- Airport Collaborative Decision Making (CDM) project manager/APOC Supervisor
- Ground Handling Agent
- Strategic and CDM Manager – Aircraft Operator Agent

A detailed description of these roles can be found in [18].

IV. GAMING TECHNIQUE

A. Definition

Human-In-the-Loop (HIL) Gaming technique are "serious games", designed for a specific purpose other than pure entertainment. These games are played with persons (mostly, experts) acting as actors and allow the exploration of concepts and definition of roles and processes in a structured way focusing the players' attention on the information flow and responsibilities associated to the processes. HIL Gaming technique has proven to be an excellent technique to explore the situation awareness and the human-human and human-machine interactions in automated environments [8, 9, 10] because it enables a research team to:

- learn about systems that have not been developed yet,
- study the behaviour of the people and/or machines' interactions with lower and controlled cost (compared to prototypes)
- stimulate actors to be open-minded and obtain results from different points of view.

Experience in ATM assessment has proved that the combination of role-based games using paper with role-based games using hardware-platforms provides a good quality assessment of the process involved in the concept under test [9, 10]. Paper-based games are performed using basic office material. They are basically board games where the rules are designed according to the processes and roles interactions to be studied/ clarified. Hardware-based games are basically performed in the same way as the paper-based ones, but the means/tool to play is a hardware platform. The platform contributes to execute the exercises in a more realistic context and subsequently, their results are more reliable and accurate. Other benefits of these games which complement the results obtained from paper-based games are: the availability to use more complex game rules, easier to analyse performance, and closer link with different levels of automation.

Combination of both techniques will allow the definition and exploration of roles and their responsibilities and the interaction of these roles within an automated environment in two steps. Firstly, through paper-based games, obtaining the high-level results and next through hardware-based games, in which paper high-level and preliminary outcomes will support the platform/s configuration and also they will be the baseline used to produce the final results.

B. Process

During the preparation phase the general objectives, the roles and the processes to be studied are identified and detailed. Then, different Gaming Sessions are planned in order to reach these objectives step by step. Also this phase includes the configuration or adaptation of the platform to be used.

The following phase is the conduction of the gaming session and the execution of the games with the selected players. This is the less time consuming phase, but it will only be satisfactory if the preparation phase has been carried out thoroughly and when intermediate results are used where necessary to adjust the remaining gaming sessions.

The main elements to take into account in the design of the gaming session are the following:

- Scenarios: These scenarios will define the context of a gaming exercise. They include the specific objectives to address, the initial expectations and hypothesis and the geographical and temporal context.
- Selection of gaming techniques: This selection will depend on the objectives and expected results, the budget allocated to the gaming sessions and also the time constraints. As explained before, paper-based and hardware-based gaming techniques were selected for ADAHR.
- Selection of players: This is one of the main success factors of a gaming session. The players should be selected according to different factors such as the role, the gaming objective and the personality of the player. It is important that the same players participate in all games of the session to maintain the built-up knowledge. ADAHR counts on the available expertise within the SJU and EUROCONTROL for its gaming sessions, which increases considerably the chances on a successful end of this project.
- Rules to be applied during each game: Rules are one of the main components in a game and they define how each game should be undertaken.
- Tools to collect the outcomes: These elements are important to establish the methods to compile the results. Some examples are questionnaires, comment sheets and debriefing techniques (technique to obtain conclusions from the participants at the end of each game or gaming session).

C. Hardware-based Platforms

ADAHR will use two hardware-based platforms to assess the two different environments: ACCES (Airport Control CEnter Simulator) and CHILL (Collaborative Human-In-The-Loop Laboratory).

1) ACCES Platform

The airport gaming exercise requires a facility to use as an airport operations center (APOC), in which several operator working positions as well as a common overview of the situation to those operators is provided. ADAHR will use DLR's ACCES facility for this purpose, which provides a flexible infrastructure with up to ten operator working positions as well as a large power wall to show a situation overview to all operators, see Fig. 1. All working positions are equipped to access different PCs running CDM and stakeholder specific systems as well as Voice over Internet Protocol (VOIP) communication.

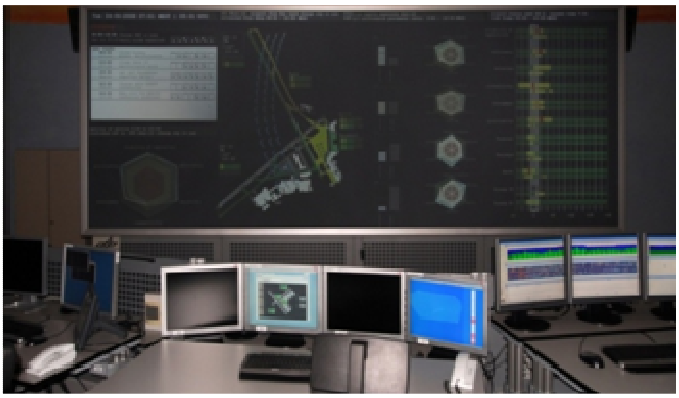

Figure 1. APOC simulator ACCES.

The airport agents will be supported by a new collaborative planning tool, the Total Operations Planner (TOP). The TOP is a pre-tactical planning tool capable of planning all flights of the day taking into account the flight schedules, agreed performance parameters (e.g. capacity, throughput) for the airport as well as user preferences. Stakeholders can initiate what-if planning to evaluate the response of the overall airport performance to changes in input parameters. A full airport processes simulation supports the experiment by providing very realistic data for all airside and landside processes considered during the exercise.

2) CHILL Platform

CHILL is a versatile collaborative ATM validation platform in which different categories of actors can work together to efficiently manage traffic demand and capacity, exchange ATM data and share information in support of a collaborative Air Traffic Flow Management (ATFM) planning process. The CHILL modelling Platform has been designed as a suite of interoperable modelling services and components to support the evaluation, performance assessment and validation of existing and future ATM concepts of operation.

The CHILL platform can be adapted according to the gaming requirements (rules, protocols of performance of the different actors, processes and interactions between automatic and human agents...), see Fig. 2.

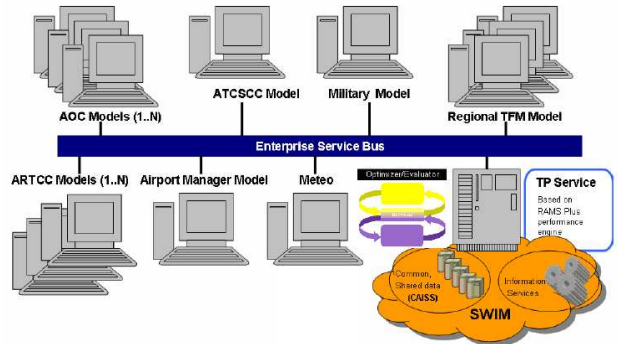

Figure 2. CHILL structure adapted to Gaming.

V. CONCLUSIONS

The ADAHR project will use Gaming Techniques to assess the impact of high levels of automation on human roles, with a time horizon beyond 2020. The better understanding of how automation may change the strategies and responsibilities of several ATM roles will enable the members of the ATM community to identify their real future needs. Furthermore, the research falls perfectly within the scope of SESAR's WP-E, by bringing new solutions that will provide benefit for both on the short and on the long term. On the short term, adding value to the existing SESAR work by identifying new responsibilities and gaps in the evolution of human roles defined in SESAR by analyzing the interaction with the new automation levels in the CNS/ATM system and helping defining future functionalities of new tools. And for long term, thinking beyond current SESAR timeframe, by assessing and clarifying new human roles and responsibilities as a result of the use of advanced tools with high levels of automation.

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