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.
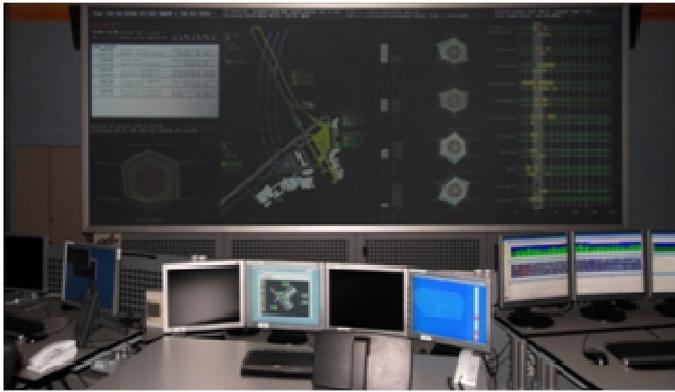
Figure 1.   APOC simulator ACCES.

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.
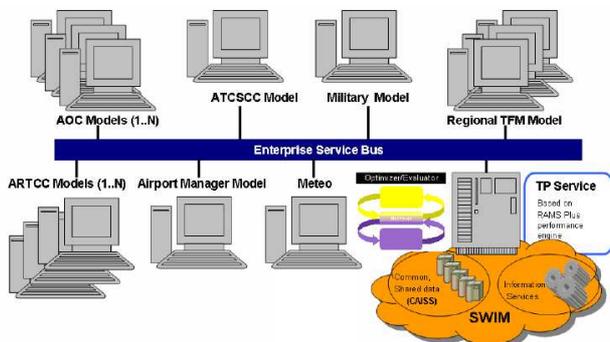

Figure 2.   CHILL structure adapted to Gaming.

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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