Feasibility study of Flight Centric Mode of Operations

A Human Performance Approach

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***Abstract*—We investigated the operational feasibility of Flight Centric ATC with a Real-Time Simulation in an area covering Budapest Area Control Centre between FL325 and FL660. This exercise specifically looked into single-person operations, where the ATCOs fulfilled the roles of conventional Planning Controllers and Executive Controllers. From a Human Performance perspective the main goals of the validation exercise were to collect controllers' feedback regarding i) the set-up of responsibilities and tasks allocated to them, ii) the impact of the changes in operating procedures on human performance, including controller's trust, workload and situational awareness and finally, iii) assess the display design for presenting the Flight Centric airspace on the controller working position. The results clearly show that the new concept has significant impact on situational awareness. In order to support controllers, reliable and transparent Flight Centric-specific system support is essential, which has to be further refined. Data also indicate that whilst workload remained at acceptable levels, major contributing factors were coordination needs and management of the new tools. The paper outlines the conclusions and recommendation for the next phase of research.**

Flight Centric Airspace; Flight Centric Planning and Executive Controller; Workload; Situation Awareness; HMI

I. Introduction

In current operations the airspace of an Air Navigation Service Provider is subdivided into sectors and the sector team is responsible for all aircraft within an ATC Sector. This team normally consists of an Executive Controller (EC) and a Planning Controller (PC). The EC is responsible for separation provision and collision avoidance. The PC is mainly responsible for the planning and coordination of traffic within the ATC sector, including the monitoring of aircraft entering and leaving it. Furthermore, the Planning Controller provides tactical flight control assistance to the Executive Controller as needed. The PC also serves as "second pair of eyes" and a backup of the EC.

Coordination with other ATC Sectors is done via system coordination, telephone, elbow coordination or hotline. Every aircraft expected to enter the volume of airspace of a sector is assigned to the team in charge of that sector. That means that during its flight an aircraft may go through several sectors hence through several controllers. Each sector is assigned a sector capacity, i.e., number of flights per hour which are allowed to enter the sector. Sector capacity is determined for each sector and depends on many factors, e.g., traffic flows, potential conflicts points, or probability of vertical movements of the aircraft [1]. The capacity of the sectors is monitored, and should not be exceeded. In case of an expected overcharge in a sector, there are different possibilities to reduce it: level capping, re-routings, delays on ground, etc. Another possibility is to reduce the sector's size by dividing the sector into smaller sectors. Each of these smaller sectors is then assigned its own pair of controllers with its own sector capacity. However, as previous studies have pointed out, increasing the number of sectors leads to an increase of coordination activities and to the reduction of the possibilities for controllers for tactical and strategic control of aircraft [1] [2].

The idea behind Flight Centric ATC is to dissolve sector boundaries, that is, a sector team is no longer in charge of managing the entire traffic within a given sector[1]. In other words, controllers are assigned individual aircraft, which no longer have to be in the same geographic region, but may be distributed over the entire airspace. Consequently, the pilot has fewer frequency changes during the entire flight and there are no constant handovers from one controller to the next [1].

Flight Centric mode of operations was first introduced by [3] in 2001 and since then it has been further developed to cover tools, tasks and operating procedures [4][5][6][7][8]. These previous studies however, had some limitations in their human factors assessment using human-in-the-loop simulations. Therefore, in the exercise reported here, single person operations (SPO) in Flight Centric Airspace (FCA) were tested, where the controller fulfills the roles of conventional Planning Controllers and Executive Controllers

[1] There were four validation exercises in this SESAR Solution (PJ10-01b) covering different operational environments, operational procedures, actors, tools, KPAs, KPIs, and R&D needs. This paper is based on one of these exercises. In other words, there are different approaches to implement Flight Centric ATC and we are reporting just one of them.

(hence the name Flight Centric ATC Planning and Executive Controller, or Flight Centric PEC). SPO is a well-known mode of operations [9] and also used at HungaroControl in the Kosovo (KFOR) sector. According to the new mode of operations, the Flight Centric PEC is in charge of a certain number of aircraft throughout a significant part of their route segment within a given airspace, whereas other controllers are responsible for different aircraft within the same airspace. The number of Flight Centric PEC depends on the number of aircraft present at any given time in the airspace. In addition, only one controller is in charge of an aircraft at any given moment. Therefore, this concept entails the potential to balance workload between air traffic controllers (ATCOs), provided that the traffic allocation works efficiently and reliably (see Methods section for more information).

ATCOs still have the responsibility for separation provision and have to ensure a conflict-free flight, as well as safety and optimization of traffic flows. That is, the basic responsibilities of the controllers do not change, but team structure, task distribution and methods of operation do. As the controllers do not have the full picture of the whole Area of Responsibility (AoR), situational awareness (SA) is expected to be strongly impacted [10]. In order to ensure that they are kept in the loop, tools must be adapted to the new FCA environment, and new tools or functionalities must be introduced. Those under consideration were[2]: the allocation support function, the complexity-based prediction function and the less impacted flight algorithm (LIFA), all closely related (see Methods section). Coupled with the required changes in the tools, operating methods are also expected to change significantly in the following areas:

- Flight allocation strategy: Traffic assignment was automated through the allocation support function, based on the complexity of the traffic situation for an air traffic controller;
- Separation provision and monitoring: The Flight Centric PECs are responsible for separation provision. Like today, conflict detection and resolution tools (CD&R) are available to support them. However, as the area to monitor is significantly larger than in the sector-based operations, efficient system support for conflict detection is mandatory (i.e. filtering functionality). With regards to conflict resolution, the conflicting traffic inside the Flight Information Region (FIR) might be under the control of different Flight Centric PECs. In order to reduce the need for coordination between ATCOs and maintain situational awareness, the responsibilities for conflict resolution have to be determined and clearly presented to the ATCOs.

The main goal of this exercise was to investigate the operational feasibility of Flight Centric ATC in an area covering Budapest Area Control Centre (ACC) between FL325 and FL660. At V2 maturity, the main goals of the validation exercise, from a Human Performance perspective, were to collect controllers' feedback regarding:

- The suitability of the role, responsibilities and tasks of the Flight Centric PEC;
- Impact of changes in operating procedures in Flight Centric mode of operations, including the automatic assignment of aircraft to ATCOs; the procedures for conflict detection and resolution; the coordination between controllers inside of the Flight Centric Area and between sectored and FCA operations (including conflict management);
- The impact of Flight Centric mode of operations on human performance, including controller's trust, workload and situational awareness;
- The display design for presenting the FCA on the controller working position (CWP).

II. Methods

A. Scenarios

The exercise consisted of a Real-Time simulation, which took place at HungaroControl in January 2019, and investigated the operational feasibility of Flight Centric ATC in an area covering Budapest ACC between FL325 and FL660. This area today is already a free-route airspace [11], a specified airspace in which users may freely plan a route between defined entry and exit points, with the possibility to route via intermediate (published or unpublished) waypoints, without reference to the ATS route network and subject to airspace availability. Within this airspace, flights remain subject to air traffic control.

The simulation had a 2×2 factorial design, with Concept (Reference *vs.* Solution) and Traffic complexity (En-route medium *vs.* En-route high complexity) as between-subjects factors. Five sectors were simulated in the Reference runs (UPPER, HIGH sector with two geographical cuts, and a FIR-wide TOP sector). In order to assess the implications in FCA with the same amount of ATCOs, 10 FCA CWPs were set up in the Solution scenario.

In the Solution runs the medium complexity traffic scenario had approximately 55 aircraft at a time, whereas the one of high complexity had 73 aircraft. The Reference runs had 10-12 and 14-16 aircraft per sector in medium and high complexity, respectively. The medium complexity runs in both cases (Reference and Solution scenarios) included 12 climbing and 13 descending aircraft, for a total number of 240 flights. The high complexity runs included 20 climbing and 25 descending flights for a total number of 322 flights.

B. Simulator and system support

TrafficSim platform of DLR was used for the Solution runs, MATIAS BEST of HungaroControl for the Reference runs. MATIAS BEST, which is also the contingency platform with the same software as in the OPS room, is used for training and validations by HungaroControl. Tool behavior, especially

[2] The feasibility of an FCA-specific communication tool (wide-area communication), developed by Frequentis, was also investigated, but the discussion is out of scope of this paper.

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the parameters (e.g. look ahead time of Medium-Term Conflict Detection tool, or MTCD) and the presentation of the tools on the Human-Machine Interface (HMI) (e.g. radar and flight plan separation tools) were harmonized to a certain extent between the platforms. The layout of the radar display and especially the interaction via aircraft labels were modelled to resemble the look-and-feel of the radar display used by HungaroControl in daily operations. One important difference was the relatively large radar tile to display the complete FIR (i.e. through a horizontally broader monitor, see Figure 1 [10].

Figure 1. DLR's TrafficSim at HungaroControl Simulation HUB.

Furthermore, the TrafficSim included several tools and functionalities which specifically support Flight Centric operations. The most prominent of these was an allocation support function that enabled a dynamic distribution of incoming aircraft among the controllers following a certain predefined set of rules. It received input from a complexity-based prediction function, which assessed the complexity of the traffic situation for an air traffic controller, taking into account e.g., individual trajectories, number of assigned aircraft, number of probable conflicts and vertical movements.

Another functionality exclusive to the TrafficSim was the less impacted flight algorithm, that calculated which flight was less impacted if a selected conflict resolution action was applied, based on different criteria. The use of this algorithm was applied to two different processes, flight allocation and conflict resolution, each with a different time horizon:

- Allocation Strategy (before entering the FCA): the entering flight was allocated to a Flight Centric PEC based on criteria such as workload and potential conflicts. If the entering flight was predicted to have a conflict inside the FCA with another flight, then the LIFA was used to determine which the best resolution method was. The flight less impacted by this resolution was then used as an input for the final allocation to the Flight Centric PECs.

- CD&R tool (once the flights are inside FCA): if a conflict was detected between two flights inside FCA, the LIFA was used to determine which controller had to solve the conflict, and provided a ranked list of resolution proposals based on criteria such as extra miles (fuel consumption) or traffic complexity. If deemed insufficient, controllers could deviate from the recommendations.

One final functionality of relevance was the Filtering function. In Flight Centric mode of operations information granularity must be adequate for task execution and for information presentation. Therefore, filtering must be applied in order to keep the information (e.g. traffic in the vicinity of one's traffic) on a level that can still be processed by the controller. In this new operational environment controllers need to be kept in-the-loop regarding all events taking place that involve aircraft under their responsibility, including potential interactions with aircraft under the responsibility of other ATCOs.

C. Participants

Eleven controllers participated in the validation. Their ages ranged from 26 to 52 years old (M=36.2, SD=10.9) and their experience as controllers ranged from 1 to 28 years (M =10.7, SD=11.0). This meant participants included younger and older controllers with relatively little to a lot of experience, which allowed us to collect feedback from ATCOs with different perspectives. Participants gave their written informed consent prior to their inclusion in the study and the simulation was conducted according to the principles expressed in the Declaration of Helsinki [12].

D. Procedure

As indicated, the Real-Time Simulation required ten ATCOs working in five sectors in the Reference scenario (five ECs and five PCs) and ten Flight Centric PEC in the Solution scenario. In addition, there were five pseudo-controllers representing both the PCs from Hungarian airspace below FL325 (sectored) within the FIR, and the adjacent units outside the FIR. Coordination between ATCOs and the Supervisor and other roles was out of scope for this exercise.

Training took place over two days. The first day consisted of theoretical training with presentations about SESAR, the Flight Centric concept, explanations of Reference and Solution runs, and the Human Factors analyses (namely, the questionnaires). The second day was dedicated to the training on the TrafficSim.

The eight validation runs were split into two days: two Reference runs that took place on day 1 (one with high and the other with medium traffic), and six Solution runs (three medium and three high traffic runs) on days 1 and 2. Controllers rotated through the ten positions in the FCA runs and switched positions between the two Reference runs, working both as EC and PC in two different sectors. There were four runs per day with breaks in-between. Each run lasted for 60 minutes.

Therefore, the experimental design was not completely balanced in order to have the ATCOs experience the Solution scenarios as many times as possible, whilst also having Reference runs to compare to.

E. Questionnaires

During the runs every 2 minutes the Instantaneous Self-Assessment (ISA) workload scale [13] popped up on a tablet next to the ATCOs with a loud beeping sound. The Controllers then had 30s to select their workload levels on a scale of 1 to 5 (ranging from Underutilized / Relaxed / Comfortable / High / Excessive).

After each run they filled out standard Workload (Bedford and the short version of AIM [14]) and Situation Awareness (SASHA [15]) questionnaires, and specific questions about the events that took place during the previous run. In particular, we wanted to find out what the controllers felt regarding the behavior of the tools, their coordination needs and the procedures applied for conflict detection and resolution.

At the end of day 1, that is, after experiencing two Reference runs and two runs in FCA (one medium and one high), the ATCOs filled out one short questionnaire to collect some initial feedback on their tasks and the system. This was followed by a relatively long debriefing with the controllers split in two groups together with Human Factors and system experts to discuss the events that took place on that day. At the end of day 2, the ATCOs filled out a longer, more detailed tailor-made questionnaire related to the success criteria (Operational and Human Performance-related specific questions). These had a Likert response format with seven possible answers, ranging from strongly disagree to strongly agree. After a certain number of questions on the same topic, a free text question was inserted to allow the controllers to provide additional comments or explain their answers.

The SASHA, ISA, Bedford Workload Scale and AIM data were analyzed in order to compare the conditions. The figures were generated in R software. The results of these questionnaires thus provide an initial understanding of the impact of FCA, however, they are complemented with the feedback gathered from the tailor-made questionnaires and the debriefing sessions. The Results section of this paper aims to provide an overview of the main outcomes of the study and the recommendations for further research in the next SESAR wave.

III. RESULTS

A. Tasks and Operating Procedures

Controllers did not report major issues with the identification of conflicts by the system. Most of them agreed that the TrafficSim correctly predicted conflicting situations, but requested some changes in the detection algorithm. The TrafficSim was programmed to signal a conflict every time the required separation between two aircraft was violated (e.g., 6 NM), however in real life controllers react before this distance is reached. Therefore, when a conflict was detected, the ATCOs still had to analyze the situation and react, losing precious time. For this reason, they requested a warning before a predefined distance between aircraft is reached (e.g., 10 NM in case of on track/head on).

Regarding the support provided by the TrafficSim for conflict resolution, it was clear from the discussions with the controllers that the advisories need to be improved, they should be more efficient, realistic and the number of alternatives reduced. Whilst the controllers found it useful that the system assigned the delegation of responsibilities for conflict resolution (reducing the need for coordination), they were not always happy with the system's suggestions on who should solve the conflict. As the conflict resolution suggestions were met with some concerns, coordination was regarded as crucial to find efficient solutions. In the high traffic complexity, for example, there were multiple conflicts and the need for coordination with other Flight Centric PECs was mostly triggered by the dissatisfaction with the solutions for conflict resolution presented by the system. This also goes to show the importance of further addressing cases with multiple conflicts, as four controllers reported having to coordinate with more than one colleague to solve a conflict. In order to notify other colleagues about a change (e.g. heading, speed) while talking to an aircraft, controllers would have appreciated the availability of electronic coordination. The lack of this functionality in the TrafficSim (except text message exchange) further impacted efficient task execution. In MATIAS BEST the controllers rely on electronic coordination, and the fact that something similar was not available to them in TrafficSim was met with some concern.

Controllers felt that some conflicts could have been avoided with a better allocation. In other words, from their perspective if conflicting aircraft were under the responsibility of different controllers this should have been prevented by the allocation process – the aircraft should have been with the same ATCO to begin with. However, even with an improved allocation functionality the system cannot predict and consider in advance all possibilities associated with changes in flight path instructed by an ATCO or even requested by a pilot.

B. Situation Awareness and Workload

Comparisons between Solution and Reference scenarios in levels of Situation Awareness (SA) and Workload need to be done carefully, considering the different number of runs and the difference in the degree of experience with both platforms. Controllers were very familiar with MATIAS BEST and its tools, whereas the TrafficSim platform is new and still under development.

According to the results of the SASHA questionnaire, situational awareness levels were both relatively high in the Reference and in the Solution runs (see Table I). However, the ratings also suggest the presence of a learning effect in FCA, with SA ratings increasing from the first to the third run, especially in FCA High. In general, even though for each traffic scenario SA ratings are higher in the Reference than on each of the FCA runs, by the third FCA run they were not much different.

TABLE I. AVERAGE AND STANDARD DEVIATION OF SASHA RATINGS IN BOTH SCENARIOS IN HIGH AND MEDIUM TRAFFIC COMPLEXITY.

Scenario	SASHA ratings				
	1	*2*	*3*	*Average*	*Standard Deviation*
FCA Medium	4.2	4.98	5.1	4.76	1.1
Reference Medium	5.5			5.5	0.3
FCA High	3.6	4.06	4.8	4.1	0.8
Reference High	5.1			5.1	0.6

Even though in their answers to the standard SASHA questionnaire the controllers did not report low Situation Awareness, their subjective assessment through further questioning was not as positive. According to the general impression, ATCOs reported not having the full mental picture of their AoR. When asked to explain why their SA levels were not good, the controllers mentioned problems with aircraft filtering and with the user interface.

One important component of situation awareness is the possibility to plan ahead and look into the future. When asked whether they had more time to do that in the FCA runs compared to the Reference runs, most of the ATCOs said they did not. The general planning process was claimed to become more difficult, as sometimes there were too many aircraft on the TrafficSim display (even with the filtering on). In addition, no complex vertical movements could be planned, which had a significant role in the decreased SA. Together with the improvement of this algorithm, the inclusion of the Probe[3] tool to be used outside the FCA (i.e. for a/c before entering the sector) would also be strongly recommended to support the planning task.

Table II indicates the average for ISA ratings in the FCA and Reference scenarios (high and medium traffic). Data suggest that workload levels show a tendency to decrease with each run in FCA. Controllers reported the highest workload levels in the Reference high complexity scenario and the lowest on day 3 of FCA medium scenario.

[3] The Probe ATCO decision support tool creates tentative trajectories showing the risks which may occur if certain changes to the flight plan (e.g. level change, heading) were applied.

TABLE II. AVERAGE AND STANDARD DEVIATION OF ISA RATINGS IN BOTH SCENARIOS IN HIGH AND MEDIUM TRAFFIC COMPLEXITY.

Scenario	ISA ratings				
	1	*2*	*3*	*Average*	*Standard Deviation*
FCA Medium	1.89	1.63	1.57	1.69	0.56
Reference Medium	EC = 1.83 PC = 1.64			EC = 1.83 PC = 1.64	EC = 0.54 PC = 0.65
FCA High	2.58	2.22	1.97	2.26	0.73
Reference High	EC = 2.71 PC = 2.45			EC = 2.71 PC = 2.45	EC = 0.89 PC = 0.63

Whereas ISA assessed workload levels during the runs, the Bedford questionnaire was filled out post-run and presents a slightly different picture (Figure 2). Here the FCA runs (in Medium and High traffic complexity) had higher workload scores than the Reference scenarios. However, Bedford ratings are in general relatively low in the Reference runs, and even the FCA ratings are perfectly acceptable.

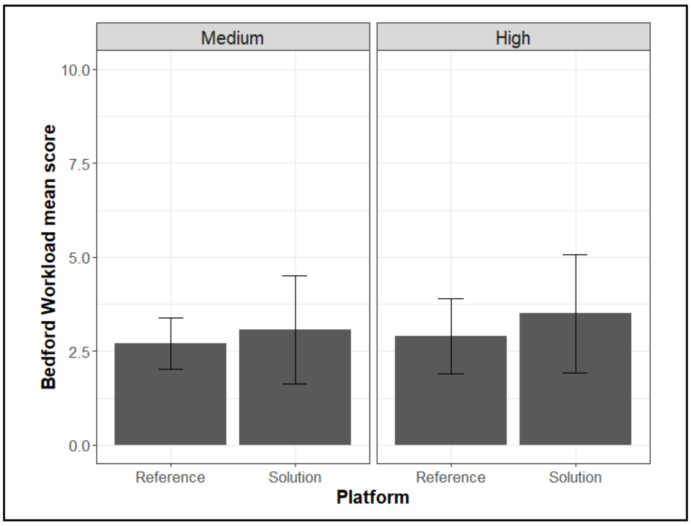

Figure 2. Mean scores of the Bedford Workload Scale, separated by traffic complexity and platform. Error bars show the standard deviation.

The AIM tool was then applied to understand which aspect of automation had the biggest impact on workload levels. The overall means and standard deviations are reported in Figure 3. AIM has 16 sentences, each describing a task usually performed by the controllers during their normal working period. A final rating of zero means that no effort was spent in any of the 16 tasks during the preceding run and that the controllers felt they had nothing to do (boredom). This happened in five instances (all in FCA runs), that is, the controller filling out the questionnaire gave a rating of zero to all tasks. Here the two high traffic scenarios (Reference and

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FCA) had higher workload scores than the medium traffic scenarios. However, AIM ratings are in general relatively low.

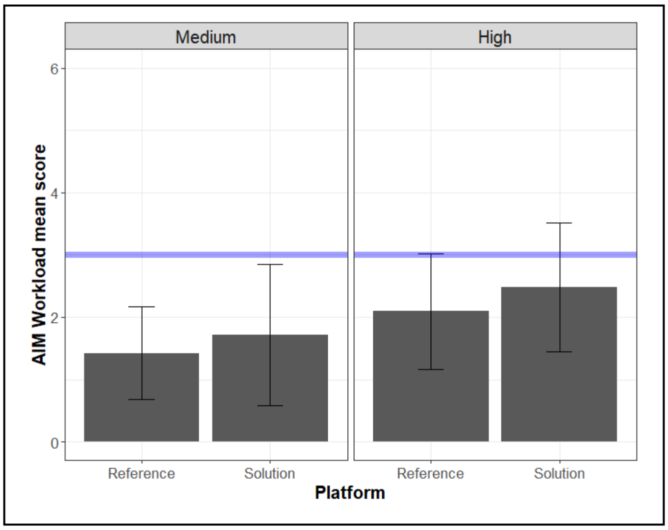

Figure 3. AIM mean scores separated by traffic complexity and platform. Error bars show the standard deviation. Blue line represents the middle of the scale.

A look at some of the comments written after each of the medium traffic runs supports the data, as several controllers complained that there was not much to do in the FCA medium environment. The only source of workload seemed to have been caused by i) the need for coordination, ii) using the new tools (lack of experience) or iii) HMI weaknesses and system bugs. As already mentioned, Flight Centric PECs needed to coordinate with sectored airspace inside and outside the FIR, and also with the other Flight Centric PECs. With regards to the new tools, based on the feedback received their ease of use could be improved with more training. As one controller explained: "In the FCA [...] I had to use tools which I don't use regularly unlike in MATIAS BEST. But later on after I practiced the tools and tried to change my mind set it became easier. Most of the time I had to do less in the FCA than in MATIAS BEST especially when I had only overflying aircraft". However, and confirming previous statements, most controllers agreed that some TrafficSim functions increased workload ("Using the tools demanded too much effort in a way that a clear comparison is not possible for me to make between the two systems"). Finally, during the high traffic complexity runs, system bugs and interface problems caused more problems than in medium traffic and hence some workload. The inefficiency of the conflict resolution advisory also contributed to some workload. As one controller put it: "Basically workload is really low, even if we have 10-12 aircraft, but analyzing these bad solutions [bad conflict resolutions suggestions], then analyzing the situation, and coming up with an applicable, good solution is the 100% of the workload".

C. HMI

In general, the controllers agreed that conflict warnings were correctly activated and terminated when a conflict was detected; that in case of conflict between two aircraft under the responsibility of different ATCOs it was clear which ATCO should solve it; and that the aircraft under their responsibility (assumed) were clearly marked and could be easily identified. They reported, however, problems with how data were displayed (in order to provide separation between aircraft for conflict detection and resolution). In particular, the information was available to the controllers in the HMI menu, but was difficult to find (i.e. speed, heading, level change). It should be pointed out, though, that the controllers were not as familiar with the TrafficSim as they were with MATIAS BEST, where they can access the information much faster, simply because they are experts in using it. Finally, controllers also felt that sometimes there were too many aircraft on the TrafficSim display (even with the filtering on). In fact, the controllers mentioned several times that the filtering algorithm needed to be improved, not only to keep it from showing irrelevant aircraft, but also to show some aircraft earlier. This filter should be a dynamic one, allowing to probe a different level band and/or trajectory, and temporarily displaying the appropriate tracks on the HMI, according to the probed level band/trajectory. Such a dynamic filter would support enhanced conflict detection and resolution advisories both for level changing aircraft and overflights, and it would also ensure a better "flight awareness" for the controller showing only the relevant traffic for each and every flight which is under his or her jurisdiction.

When a conflict was imminent, both ATCOs should be aware what the other is planning/doing. So, some modifications on the HMI were recommended. In particular, if one of the ATCOs is instructing an aircraft to turn / climb / descend, the relevant field on the HMI of the other ATCO should be highlighted. Also suggested, is the possibility to request a certain maneuver from the other ATCO. In this way, even without verbal coordination/frequency change, all the ATCOs involved would have the SA, and they could make their decision with less delay. To account for the workload induced by the system in the simulation, suggestions were made to improve the usability of the HMI (e.g. to display heading and speed information in the aircraft label, to enable the modification of exit flight level or requested flight level in the label), as well as reduce the number of clicking necessary to perform some actions.

IV. DISCUSSION

At V2 maturity level it is not surprising that, given the scope of change compared to current procedures, participating controllers would have a lot of comments, suggestions and criticism regarding operating procedures and tools. These were broken down into tasks/operating procedures, Situation Awareness/Workload and HMI.

Even though roles, responsibilities and task allocation were understood, the extent of all changes associated with the new operating procedures in Flight Centric mode of operations still need to be further clarified. In terms of tasks, the most relevant changes with respect to today's operations are the changes in responsibility for conflict detection and resolution. This is a paradigm shift in which the responsibilities do not necessarily fall in one single controller in charge of a certain flight but might be shared with one or more controllers. In order to support the ATCOs and increase SA, the exercise presented in this paper applied the LIFA algorithm to provide clear instructions as to who should solve the conflict. The HMI also provided unambiguous notification to the responsible controller. Nevertheless, given the large geographic area covered and the number of ATCOs involved, system support should be further enhanced.

The first key function to be improved thus is the filtering mechanism. In conventional environment the number of scanned aircraft is limited and determined by the sector load. That is, controllers do not scan unconcerned aircraft for conflict, even if they are present on the HMI. In Flight Centric mode of operations this changes the moment that other aircraft under the responsibility of other controllers share the same geographic area. Without an efficient display, situational awareness can easily become fragmented.

On that note, controllers stressed the importance of further developing the conflict resolution advisories and the HMI supporting the conflict resolution actions. Firstly, the suggestions should be based on more logical strategies, bearing in mind that ATCOs also communicate verbally, which can overwrite the pre-set rules, making it hard to generate exact formulas. Secondly, increasing the transparency of the suggestions could be of great help to maintain situational awareness. According to discussions, a potential key to boost SA is to provide the controller with all information necessary to enable an understanding of the reasons for the advisories presented to him. Such an explainable Artificial Intelligence could pave the way for establishing a Joint Human Machine System [16] and contribute to building up trust, hence acceptance.

The impact of FCA on workload was also assessed. Contributors of interest were coordination needs, management of new tools and HMI layout. Difficulties with the coordination of external conflicts is expected to translate into real-life situations as well, also because two factors have to be aligned, over which the FCA controller has no influence over: silence on frequency and controller workload at the other end of the line (i.e. they might not be able to answer immediately). The question of external conflicts will be assessed in Wave 2 by addressing cases of FIR exiting conflicts/sequencing in a more structured manner.

The need to better understand the intent of other controllers operating in the same area was also identified as a key point for the implementation of the Flight Centric mode of operations. Coordination mechanisms need to be developed to ensure that what-if and what-else solutions are sent to the affected controllers, especially in those situations that are not predictable. In any case, when a third party is involved in the solution of a conflict, it is very difficult to manage the situation. Here, clear operating procedures need to be in place to support the controllers in addressing multiple conflicts between aircraft under the responsibility of different controllers.

Allocation strategy may also be further improved to ensure balanced workload and optimized distribution of conflicts. Nevertheless, it needs to be considered that relatively low levels of reported workload might have been achieved at the expense of (low) situation awareness. Better tools will increase trust in the system but, most importantly, situation awareness must increase, even if workload also increases.

A. *LIMITATIONS*

Whilst we firmly believe that this V2 exercise was able to deliver valuable input to the question of feasibility of flight centric mode of operations and its impact on the ATCOs, some limitations of the simulation need to be highlighted.

In terms of workload, it was expected that the distribution of workload levels for each controller over time would be better in FCA, since they always have an optimal number of aircraft under their control based on the current and predicted traffic load. In addition, complexity-based allocation of traffic should allow for better distribution of the traffic between ATCOs which would contribute to avoid cases of high workload experienced by just one controller. Finally, both overload and underload situations occurring in sectors nowadays would be distributed over longer routes in larger airspace. However, we were not able to obtain the required evidence to confirm this, since overload and underload situations would need to have taken place in the Reference scenario (current sector environment) to show that they would be less common in Flight Centric mode of operations. However, no clear overload and underload situations were identified within the same run during the Reference scenarios. Reasons for that were the i) modified traffic sample, which resulted in balanced occupancy between all five sectors and ii) the fact that there were just one run in medium and in high complexity in the Reference scenario. Also, note that the experimental design was not completely balanced. The set-up of the traffic scenarios was designed to allow the ATCOs to form an opinion about the FCA concept and experience different working positions, hence traffic situations. This however had an impact on the power of the statistical analyses and the confidence in comparing the Reference and Solution runs.

Differences between the platforms made such comparison even more difficult, especially since some of the functionalities were used only in the Solution scenario. The MATIAS system is used on a daily basis for 19 years, so it is no surprise that it is more mature and advanced than the system used during the FCA runs. Furthermore, there were also differences between the platforms, e.g. in aircraft performance. However, having the sectored operations running on TrafficSim would have required extra efforts for platform development, which were not available within the project. This also had a clear effect on the evaluation process.

Controllers also found it extremely difficult to separate performance of the system (how well it supported them) and operating procedures associated with Flight Centric mode of operations. Most of the input from the ATCOs was focused on how they were able (or unable) to perform their tasks with the tools at their disposal. Therefore any objections to the tools were also a criticism of the FCA concept.

Consequently, more runs are required to allow for better evaluation of the concept, so that the assessment of the operating procedures in Flight Centric airspace can be separated from the assessment of the tools. These runs should be iterative, meaning there should be enough time for technical modifications between evaluations, to enhance the ability to assess the concept and ensure a human-centered design approach. The next phase of research would also allow to test the feasibility of flight centric mode of operations in a more realistic and complex operational environment (e.g. adverse weather conditions, more North-South crossings, avoidance of Temporary Segregated Airspace).

V. CONCLUSION

Given the findings above, it is clear that Flight Centric mode of operations requires a complete change in the perception of situational awareness, as well as high levels of automation of certain tasks. Therefore, it is not surprising that controllers reported low levels of "traditional" situation awareness, especially in the high complexity operational En-Route environment. A better definition of situation awareness in the FCA context needs to be put in place, in addition to an improvement of the filtering of aircraft.

An adequate level of trust in the system is also essential in FCA in order for the ATCOs to be able to perform their tasks while at the same time maintaining or increasing safety. Too much trust in the automated functions translates into overreliance on automation, whereas lack of trust on the benefits brought by the operational changes associated with FCA has a detrimental impact on the controllers' performance. Controllers reported low trust in the system, but trust is strongly linked to system development. Coupled with further system development, a potential way to increase trust is to enhance the usability of the conflict resolution advisories, combined with a more transparent algorithm to keep the controllers in the loop.

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