Flight Centric ATC: Reshaping the Supervisor Role

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***Abstract*— The Flight Centric Air Traffic Control (FCA) concept represents a paradigm shift from the conventional sector-based air traffic management approach which requires a high level of coordination and communication, and can lead to uneven workload distribution between sectors. FCA aims to address these challenges by eliminating sector boundaries and allowing multiple Air Traffic Control Officers (ATCOs) to work within the same airspace. Instead of being assigned to specific sectors, controllers are responsible for individual aircraft from entry to exit within the entire FCA airspace. This new approach promises significant benefits, including increased airspace capacity, longer lookahead time for conflict resolution, and efficient workload distribution among ATCOs, leading to a potential reduction in the number of required controllers and lower fuel consumption. The transition from a sector-based Air Traffic Control (ATC) system to the FCA concept fundamentally changes the tasks not only of the air traffic controllers, but of other roles such as the Supervisor, who traditionally oversees operations in an Area Control Center and assists controllers in managing challenging traffic situations. To define the role of the Supervisor in the FCA context, a dedicated workshop was conducted with Ukrainian air traffic controllers and Supervisors, as well as operational, safety and human performance experts. The workshop had three major goals. First, it aimed to explore how the Supervisor's general tasks and responsibilities change in FCA compared to a sector-based environment. Second, to assess the level of involvement of the Supervisors on FCA-specific operating procedures: finally, to determine which support tools are required for the Supervisor to optimally carry out these tasks.**

Keywords— Flight Centric ATC, Air Traffic Management, Air Traffic Control Officers, Sectorless, Supervisor

I. Introduction

Conventional air traffic management (ATM) divides the airspace into smaller areas defined as sectors, whose management is typically assigned to a team consisting of an Executive and a Planner Air Traffic Control Officers (ATCOs). The two responsible ATCOs monitor every flight in their sector until sector exit, providing instructions to pilots and issuing clearances, to ensure safe and efficient execution of flight maneuvers while maintaining a minimum separation. To this aim, controllers utilize a range of tools, including radar displays and conflict detection and resolution tools, as well as real-time weather data, all providing critical information needed to continuously monitor traffic flow, assess potential conflicts, and maintain a high level of situational awareness [1], [2], [3], [4]. An increase in air traffic is commonly managed by reducing the sectors' size, i.e. splitting them, in order to limit the controllers' workload, while sectors are merged to ensure a more balanced task distribution as traffic volume decreases. However, this approach presents a series of drawbacks that may limit its practicality: the coordination efforts necessary for airspace management rise with the level of fragmentation. Furthermore, as sectors become smaller, ATCOs' ability to apply tactical and strategic control is increasingly limited, amplifying the controllers' and pilots' workload and ultimately limiting airspace capacity. Furthermore, considering the current and future expected traffic demand, if no adjustments to the airspace structure are carried out, it might lead to an escalation of average delays, resulting in substantial financial losses for the aviation industry [1], [2], [3], [4].

A potential solution to address these challenges in the upper airspace is represented by the Flight Centric Air Traffic Control (FCA) concept, which moves past the traditional idea of airspace fragmentation. This new concept envisions a large unified airspace without sector boundaries, where an allocation tool ensures that every aircraft is assigned to a controller. ATCOs, no longer working in a planner-executive team but in single person operations, do not monitor a sector, but a set of aircraft throughout the whole airspace [1], [2], [3], [5], [6]. Consequently, one significant difference between FCA and conventional ATM lies in the area of responsibility, which in FCA is shared by different ATCOs monitoring different aircraft in the same airspace: also, a filtering algorithm ensures that only the most relevant aircraft are displayed in each controller working position (CWP). Within this shared area of responsibility, conflicts and related responsibilities are managed with a conflict detection and resolution tool. Whenever this tool is triggered, i.e. potentially conflicting trajectories are identified within the next 20 minutes, the ATCOs assigned to the involved aircraft are promptly notified, and responsibility for conflict resolution is unambiguously shown to them. Subsequently, the tool

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supports the responsible controller by suggesting one possible avoidance maneuver [1], [2], [5], [7].

Sharing responsibility for the airspace between all ATCOs should increase efficiency in Air Traffic Management through a more even workload distribution among controllers. As traffic demand rises or workload levels change, it is expected that the number of controllers working simultaneously and the number of flights each ATCO is responsible for can be adjusted accordingly, which may reduce the possibility of human error and increase airspace capacity. The FCA concept also effectively reduces flight time and environmental impact in terms of fuel consumption, as the elimination of conventional sector boundaries allows the aircraft to use more direct routing. At the same time, a reduction is predicted in the number of routine communication and coordination that takes place when entering a new sector, potentially leading to a lower workload for ATCOs and pilots [1], [3], [5], [8].

FCA was first conceptualized in 2001 and compared to the traditional approach by [9]. Validation activities simulating the upper German airspace as an FCA airspace in high-volume traffic conditions started in 2008 in a collaboration between Deutsche Flugsicherung GmbH (DFS) and German Aerospace Center (DLR) [10]. Initial studies by DLR examined the impact of FCA on task allocation and human performance [2], [8], [11], investigated different FCA implementation approaches [12], and explored suitable traffic information displays [13]. Subsequent research conducted within the Single European Sky Air Traffic Management Research (SESAR) framework paved the way for more extensive studies over the years. The work presented in [14] assessed the feasibility of the FCA concept through a real-time simulation (RTS) in Hungarian airspace (FL325–FL660). This was continued within SESAR2020 Wave 2 from 2020 to 2023 [7], [15]. The simulations demonstrated the operational feasibility of FCA at least under medium traffic conditions, with controllers finding procedures intuitive and workload levels acceptable. Promising results were also obtained under non-nominal scenarios, including aircraft emergency, radio failure and thunderstorm conditions [7]. Complementing these investigations, Spanish air navigation service provider (ANSP) ENAIRE in collaboration with INDRA conducted two RTS campaigns focusing on the upper Spanish airspace [4]. In 2023, a follow-up project was launched, aiming to raise the Flight Centric ATC concept's maturity to technological readiness level 6, i.e. readiness for industrial deployment, by 2026. Throughout its duration, the project partners propose to run several workshops with subject-matter experts (including the one described in this paper), a fast-time simulation, and two RTS.

As the benefits of FCA are expected to increase when applied in larger airspaces, and working towards harmonizing European airspace, DLR presented an initial roadmap for a European Civil Aviation Conference (ECAC)-wide implementation [16]. Furthermore, various aspects of the concept were investigated, complementing the large-scale validation campaigns within the SESAR program. These include an examination of suitable allocation strategies, which can be categorized into static and dynamic: static allocation assigns each aircraft to a controller based on fixed, predefined characteristics of a flight (e.g. flight direction or destination), while dynamic allocation continuously adjusts assignments in real time based on predicted or actual traffic complexity [6]. Three levels of automation can be distinguished for the implementation of the allocation strategy: automatic, where an allocation tool assigns aircraft to controllers based on predefined rules; manual, managed entirely by a human allocator; and semi-manual, which combines both approaches. In addition, specific situations might require a reallocation of aircraft to different controllers, which was explored in [3]. The concept covered in the workshop implementation assumed a dynamic, automatic allocation, aiming to balance out ATCO workload. The impact that the FCA concept may have on ATCO training was investigated in [17], concluding that a new endorsement would be required to qualify controllers to work in FCA mode of operations. [18] investigated how to design a radar display suitable for Flight Centric ATC in larger airspaces where the conventional approach of displaying the entire area of responsibility as a whole reaches its limits, and proposed a tiled display complemented by additional elements such as a timeline showing upcoming tasks and events. The new display setup was then used in a new project that focused on the influence of different levels of on-board automation on air traffic controllers and on flight efficiency in an ECAC-wide implementation of Flight Centric ATC [19], [20].

The studies highlighted that transitioning from a traditional sector-based ATM to FCA entails adapting to the new operational environment, introducing innovative systems and tools, and modifying ATM actors' tasks and responsibilities [4], [14], [16]. A key aspect that has not been investigated previously is the role that the Supervisor plays in Flight Centric ATC and how the tasks and responsibilities associated with the Supervisor in conventional ATC would be impacted. Although not formally standardized, the Supervisor traditionally assists ATCOs in challenging situations, analyzes traffic demand across the sectors and oversees daily operations. [3]. However, with the introduction of FCA, some of these tasks might be modified or even completely eliminated to ensure safe and efficient operations; furthermore, the Supervisor will have to be supported by specific tools capable of providing the most relevant information.

The focus of this paper is thus to present and discuss the results from a dedicated workshop focused on how the evolving sectorless operational framework affects the Supervisor role in an Area Control Centre (ACC). The scope of the FCA concept is limited to upper airspace within one country or one ANSPs jurisdiction, and airspaces that are classified as medium or low complexity. The workshop was organized around three major topics surrounding the Supervisor role in FCA: tasks, operating procedures and tools, as will be explained next.

II. METHODOLOGY

A dedicated three-day workshop was organized at [placeholder for review] in [placeholder for review], involving seven active ATCOs, one operational expert and three experts on safety and human performance. The participating ATCOs were all male, ranging in age between 34 and 53 years, and with operational experience of 13 to 31 years. In addition to their primary roles as ATCOs, several held additional positions of responsibility: two were Supervisors, three worked as Unit Instructors, and one was the Head of an ACC. The group represented a cross-section of operational and leadership experience, allowing insights from both controller and supervisory perspectives.

As part of the activities, all participants were introduced to the FCA concept through the simulation environment, including a specific Human Machine Interface (HMI) used for air traffic control purposes within FCA. Specifically, the workshop was structured as follows: on the first day, seven training runs were organized to familiarize the participants with the ATCO HMI (Fig. 1), and experience it in a full-hour simulation run covering nominal conditions. The HMI used in the simulation was specifically designed for simulating FCA operations over a large geographical area such as the Ukrainian upper airspace and consists of a modular radar display and a task manager. Ten radar tiles can be used to show selected aircraft and their surroundings, while the task manager supports the controller with a timeline of pending clearances, conflict alerts, and pilot requests (if received via CPDLC) and a list of all aircraft currently allocated to the controller. As the number of aircraft may exceed the number of available radar tiles, controllers select which aircraft to display. The general layout of the interface, as shown in Fig. 2, is based on a four by three grid, with the radar tiles along the outer edge and the task manager occupying the center.

The second day of the workshop was reserved for feedback collection regarding the HMI. The third and final day, whose findings are reported and analyzed in this paper, was focused on the role of the Supervisor in FCA. Specifically, the third day of the workshop was organized into three parts:

- First, the responsibilities and tasks of the Supervisor in conventional ATC operations were reviewed, and a discussion was held to assess which tasks were still applicable to the FCA concept, whether and how they needed to be modified and what new tasks would need to be introduced;
- Second, review of operating procedures developed for FCA and identification of the level of involvement of the Supervisor in normal, abnormal and degraded modes of operations within FCA;
- Finally, the tools a Supervisor would need to complete the tasks were identified and defined on a conceptual level.

The results below are organized around these three major parts and summarize the discussions between the controllers and the other subject-matter experts.



Fig. 1. Training run completed by ATCOs on first workshop day.



Fig. 2. Scheme of the FCA Human Machine Interface (HMI) layout.

Obviously, when discussing one of the topics, the other two were also mentioned given their inherent interdependency, but for the sake of clarity we will compartmentalize the outcomes of the workshop.

III. The Supervisor in FCA

In current sectored operations there are differences in working methods and operating procedures between ANSPs. The actual local deployment of the ATM concept varies globally, as well as throughout Europe, and depends on company policy, national regulations and traffic environment, among others. A particular task may be performed with the support of a specific tool, which may be different from that of a different ANSP and include distinct functionalities. In the same way, it is expected that the role of the Supervisor in Flight Centric ATC will necessarily comply with the working operational procedures and policies of each ANSP. The workshop participants provided their input based on their own working experience, but we have tried to generalize the findings to fit most ANSPs. Therefore, the views and opinions expressed in this paper are solely those of the authors and UkSATSE is not responsible for any errors or omissions. For this reason, in an attempt to focus on the most prominent issues, the discussion will be limited to the most pertinent tasks, procedures and tools of the Supervisor, and several of these will only be discussed at a higher level.

A. Tasks and Responsibilities

As a starting point for redefining the Supervisor's tasks and responsibilities in Flight Centric ATC, one of UkSATSE's Supervisors participating in the workshop was asked beforehand to review a list of tasks of the conventional ATC Supervisor and confirm whether that list was accurate and complete according to their professional experience. The original task description, used within the SESAR framework, is accessible via the European ATM Portal [21]. The reviewed list was then used in the workshop as a starting point to discuss to what extent each task would be applicable within a Flight Centric ATC setup. In the following, the main tasks and responsibilities of the Supervisor will be described in how they are affected by the implementation of FCA, based on the discussions and subsequent additional input from the subject-matter experts.

1) Analysis of traffic flows and sector load

Traditionally, the Flow Management Position (FMP) distributes information about traffic forecasts within a certain period of time to the Supervisor and the Local Traffic Manager (LTM), who will use this information to analyze traffic flows and sector loads. It should be noted that the LTM role is not implemented in UkSATSE's operations and the

related tasks will be carried out by the Supervisor instead. This analysis is sector-based, focusing on balancing workload between sectors and anticipating potential bottlenecks. In FCA, while traffic analysis remains a responsibility, the sector-based perspective becomes obsolete. Instead, Supervisors assess the overall traffic situation based on the capacity of all active controllers and prevailing airspace constraints. This shift requires a broader, system-wide understanding of traffic dynamics rather than a localized, sector-specific focus.

2) Splitting or combining of control sectors

Based on the analysis of traffic flows and sector loads and after coordination with the LTM if applicable, the Supervisor can make the tactical decision to split or combine control sectors in anticipation of upcoming traffic load. In FCA, this responsibility is transformed into the management of CWPs. Rather than adjusting sector boundaries, the Supervisor initiates the opening or closure of individual controller positions based on current and predicted traffic load.

3) Coordinating of special use airspace

In conventional ATC, the Supervisor coordinates with other concerned Supervisors (e.g. Supervisors of adjacent ACCs or military Supervisors) before the activation or deactivation of special use airspace such as military zones or temporary restricted areas. This remains a relevant task in FCA. It should be noted, however, that the degree of required coordination may be reduced depending on the scale at which FCA is implemented. For instance, in cases where a single Supervisor oversees a large FCA airspace, less cross-unit coordination may be necessary. Conversely, the implementation of FCA in large airspaces might require multiple FCA operational Supervisors sharing responsibility for the same airspace, which would lead to new coordination mechanisms needing to be developed.

4) Staffing of working positions

While the traffic load and sector capacities may require a change of sector configuration in a given situation, Supervisors in conventional operations have to take into consideration the available staff throughout a shift and their qualifications, i.e. endorsements, as controllers are trained and qualified to work only in specific sectors. When the need for a change in sector configuration arises, Supervisors determine the staffing accordingly. While controllers in FCA are still expected to obtain endorsements [22], ATCOs will be able to work more flexibly in the entire airspace without needing to retain the same amount of local, sector-specific knowledge as conventionally. Instead, required information must be available to the controller through the system easily whenever needed. Hence, the introduction of FCA significantly impacts the process for staffing a new working position, making sector endorsements irrelevant and allowing a more flexible use of controllers. The flexible nature of the concept and dynamic allocation strategies furthermore make it easier for Supervisors to consider controllers' training levels and individual competencies when opening or closing CWPs.

5) Emergency coordination; system monitoring

Supervisor tasks that remain the same the FCA concept include initiating search and rescue procedures in the event of an aircraft emergency or uncertainty, and coordinating with the technical Supervisor and other technical staff regarding the availability and reliability of ATM systems, surveillance infrastructure, coordination tools, and fallback procedures. These fundamental responsibilities ensure operational safety and resilience, regardless of the mode of operations that is in place.

6) Allocation monitoring

An entirely new task that the introduction of Flight Centric ATC requires is monitoring of the allocation process. This goes hand in hand with monitoring controllers' current and predicted workload in a tactical timeframe. With an automatic, dynamic allocation strategy based on ATCO's workload, the allocation tool provides an allocation that is already optimized for a balanced workload among controllers, as well as throughout time, without significant troughs or peaks. In normal situations and assuming the allocation tool works reliably as intended, the allocation provided by the system can be left untouched. However, manual adjustments might be required if the Supervisor notices an imbalance in workload between the ATCOs that the Allocation Tool is not automatically adjusting to. It may also be necessary to adjust individual ATCOs' capacity limits to ensure that their subjectively experienced workload remains within an acceptable range. For instance, a controller might feel that their capacity is reduced on a particular day, or a controller in training or with little experience may be assigned fewer flights than a more experienced ATCO. To ensure that workload levels are appropriate and balanced among controllers, the Supervisor should be aware of the current and predicted workload and traffic situation, communicate with the controllers and take action to mitigate workload imbalances or over or underloads, e.g. by initiating the opening or closure of a CWP. This will be further discussed below (section III.B). It should be noted that this additional task of monitoring and adjusting the allocation process may, depending on local circumstances, not be carried out by the Supervisor but a new role as suggested in section III.C.

7) Rerouting of traffic in case of overload

In conventional ATC, Supervisors coordinate with local traffic managers and/or flow managers to reroute traffic in response to controller overload. Within FCA, this function becomes obsolete, as controller's workload can be managed flexibly through dynamic allocation of flights and the activation of additional CWPs, as well as through a Workload Management Tool. Consequently, the rerouting of flights due to limitations in controller workload can be avoided.

B. Operational procedures

The research conducted within the SESAR framework [7], [19], [20] on the impact of the flight centric airspace on the ATCOs involved the assessment of operating procedures in real-time simulations via specific validation scenarios. These included nominal, abnormal (bad weather, aircraft emergencies) and degraded (ground system failures) modes of operations. To formalize the sequence of steps to be performed by the controllers, as well as the input to be provided by the system, several use cases were developed and described in [23], [24]. These also serve as the basis to write the safety, performance and technical requirements for flight centric airspace. During the second part of this workshop, the use cases were presented to the participants who were asked to provide feedback on the potential level and degree of involvement of the Supervisor. We will summarize now only the most relevant points.

1) Allocation Process

The first use case discussed described the *Allocation Process*, which is fully automated in our concept of operations. As initially developed, no human actor would need to intervene, i.e. the system would make the decisions and implement the actions (i.e., allocating the aircraft to the controllers) silently. This corresponds to Level 4 of automation as defined by European Union Aviation Safety Agency (EASA). However, workshop participants agreed that it might be necessary to override the allocation tool under some conditions. In other words, the Supervisor should always have the possibility to oversee the system and reallocate aircraft if deemed appropriate (Level 3 of automation). The question then was, at what point should that be done? The consensus was that the Supervisor should not act over the aircraft once it is "assumed" by an air traffic controller. This happens automatically once contact by the pilot is first established and the receiving controller gets full responsibility for the aircraft. The Supervisor is therefore only expected to override the Allocation Tool until the aircraft is shown in the relevant CWP's display, which is five minutes before the flight enters the Flight Centric airspace. This means that once the Allocation Tool initially allocates or assigns a flight to a specific ATCO, the Supervisor has a time window to reallocate the aircraft. The actual timeframe depends on airspace characteristics, quality of prediction, operational constraints, etc., but would vary between 20 to 5 minutes before entry. Note, however, that 20 minutes might be too early, because any inputs from the upstream controller (or even other FCA ATCOs) could impact the allocation algorithm, and the Allocation Tool might still. If the Supervisor does not act, the allocation information is sent to the corresponding FCA controller working position and to the upstream controller.

2) Conflict Detection and Resolution

The conflict detection and resolution tool identify conflicts between aircraft in the airspace, assigns responsibility for conflict resolution to one of the involved controllers, suggests conflict resolution manoeuvres and takes over guidance along the avoidance manoeuvres, if instructed. Thereafter, the controller is expected to assess the validity of the shown conflict, the proposed resolution and to issue a clearance to the flight crew. When the conflict is between aircraft under the responsibility of two controllers, they act as the second pair of eyes to each other. In other words, if needed, the controllers are encouraged to coordinate by phone or electronically in case of conflicts. Findings from the RTS executed so far [7], [14], [25] suggested that verbal coordination for conflict resolution is mostly not needed and established procedures do not compromise safety. However, there might be occasions where the aircraft are under the responsibility of the same controller who does not take action, or the second controller is unable to reach the responsible controller. In these cases, the Supervisor should act as an extra layer of safety and do something. Specific tools to support the Supervisor were then considered and are presented in section III.D.2). The bottom line is that the Supervisor should be informed of the conflicts, provided with a timeline for their resolution and be aware of any potential actions (or lack thereof) performed by the controllers. So long as the Supervisor has all available information, they can decide how to intervene, either by approaching the CWP, calling the ATCO or through specific operating procedures which still need to be defined, as an actual intervention by the Supervisor to solve a conflict was not desired.

3) Abnormal and Degraded Modes

Subsequent use cases presented in the Workshop addressed abnormal and degraded modes of operation: aircraft communication failure, aircraft emergency, meteorological conditions requiring deviation, as well as specific system failures. In all of these cases the participants agreed that coordination with the different services or units should be done by the Supervisor, because under single-person operations the ATCOs might not be able to do so due to the higher workload associated with the non-nominal event. Recall that in conventional sectored environment, the planner controller might be the one making the necessary calls in these situations. Another point mentioned were the potential announcements by the Supervisor to all ATCOs. In current operations, some events might only affect a reduced number of sectors and the details do not need to be disclosed to all. However, in FCA some overall announcements might be required, because all working ATCOs share the same airspace. Depending on the number of ATCOs working concurrently, it might be necessary to share this information electronically, instead of verbally. More specifically, the Supervisor should be able to send and receive relevant messages to/from the controllers, some of them automated by the tools. In fact, a few have already been implemented in our HMI. Emergency squawks, for example, are always seen by all relevant controllers and would also be sent to the Supervisor station. ATCOs are also able to flag any aircraft and this information is also automatically shared with all radar displays currently showing the affected aircraft. Once all relevant roles are informed, local procedures would be implemented mostly by the controllers, with the Supervisor supporting as needed.

As a conclusion, the analysis of the use cases highlighted the need for the Supervisor to be aware of the events taking place in the airspace with support from specific tools. These will be described in the third and final part of the paper. Before we cover this point, though, the question of the number and type of Supervisors will be discussed next, as this point came up several times during the meeting.

C. Team Structure

Even though in this paper we have been referring to the Supervisor as a single role, in current sectored environment there are usually several Supervisors with different functions working together, their specific tasks depending on the operating concept of the ANSPs. In general, their exact number and responsibilities is based on several factors like the predictions from the Flow Management Position (just like for ATCOs), number of open CWPs and current traffic situation (weather, restricted areas etc.). The need for several actors would not change in Flight Centric ATC airspace. For example, Technical Supervisors, system engineers who inform the Operational Supervisors about system-relevant availabilities or failures, are still fundamental. There might also be Personnel Supervisors managing the entire deployment of staff in the center (roster planning, configuration of the operational room); someone controlling the flow management in coordination with the Flow Management Position (also called Flow Supervisor in some ANSPs), a person handling administrative tasks, etc. In common, they all work under a senior Operational Supervisor, who might lead a team of several tactical Supervisors. These may be senior ATCOs: workshop participants suggested that some controllers could hold a Supervisor endorsement and hence be "back-up Supervisors").

What became clear from the input received, though, is that the Operational Supervisor would be the Supervisor most affected by the implementation of the FCA concept. So much so that the workshop participants suggested that a new role might be required if indeed the Operational Supervisor is expected to directly support the controllers as needed (particularly in case of emergencies and failures), follow overall traffic situation (including evolution of conflict alerts), manage controllers' workload and monitor and fine-tune the allocation process, among other tasks and responsibilities (including coordination with all other Supervisors and positions like Flow Management, non-FCA controllers, etc.).

Therefore, the main tasks of this new role would be to manage and monitor both the Allocation and Workload Management Tools (to be described in the next section) by constantly calibrating or tweaking them as needed, considering all available information and inputs. One example provided by the participants is when a particularly complex traffic situation is starting to develop and the allocation tool does not adapt quickly enough. The Allocator would also be the one supervising conflict resolution and intervening if a controller is not acting as described earlier in section III.B. All remaining tasks described in the *Tasks and Responsibilities* section of the paper would be mostly performed by the Operational Supervisors, who would receive support from the Allocator in monitoring the balance between demand and capacity, as well as in the opening/closing of working positions (both directly affecting workload levels).

In general, for the entire Ukrainian airspace, the workshop participants suggested that one senior Operational Supervisor could work with one Allocator at night and 3 to 4 Allocators during the day. Depending on the volume of the FCA airspace, traffic levels, etc., some roles can be combined and performed by one human actor. For example, another idea was to combine the Allocator role with the FMP.

D. Tool support

Once the tasks and responsibilities of the Supervisor were addressed, the next step was to discuss the specific tools that would be needed to support them in the Flight Centric airspace. The chosen approach was to identify the standard tools that might need to be modified, as well as new tools currently not in place. Table I presents the list of Supervisor tools covered during the discussion. Evidently, the tools would not all be operated by just one person, but distributed between two or more Supervisor workstations (as already discussed).

1) Allocation Tool, Workload Management Tool

One of the most important tools required in Flight Centric ATC operations is the allocation tool, which automatically assigns incoming aircraft to the controller with the lowest workload. The parameters considered in this calculation (with different weights) include number of climbs and descents, as well as ongoing conflicts and which ATCO is responsible for solving them. Recalculations of a controller's current workload are triggered when aircraft are transferred, when conflicts are solved or created and whenever there are route changes affecting altitude. It is thus expected that through this complexity-based dynamic allocation of traffic, controllers always have an optimal number of aircraft under their control and workload remains balanced.

However, the concept of operations under consideration assumes that the allocation process is being monitored by the Supervisor who can override it if needed. This was a very important point for the ATCOs who noted, for example, that it might be necessary to address occasional workload imbalances or emergencies. It should also be possible for the Flight Centric ATCO to alert the Supervisor in case of predicted overload. Thus, a dedicated interface to change the allocation of an aircraft before it enters the flight centric airspace is required. The process of opening/closing a CWP could also be done via the Allocation tool. Since reallocation after a controller has assumed an aircraft is to be avoided, an ATCO starting the shift would simply start receiving aircraft as they enter the flight centric airspace. At the end of a shift, an ATCO would simply stop receiving new aircraft.

Another, related, point was the possibility to adjust the thresholds of the Workload Management Tool, not only in general, but also for some ATCOs individually. The threshold in current operations is usually set at around 80 % of the acceptable workload for ATCOs. In flight centric operations it might need to be a bit lower. The ATCOs felt that there must be room for abnormal and emergency situations. Even though they suggested 75 %, this value needs to be assessed through specific validation exercises. Nevertheless, the ATCOs agreed that the Supervisor might decide that one station should receive less aircraft (through a lower workload limit), that is, they should be able to adapt the threshold for ATCOs undergoing on-the-job training, due to external factors, specific operational conditions, etc.

Any change to the Workload Management Tool would have implications not only on the allocation process (an ATCO might get more or less aircraft), but also on the assignment of responsibility to solve a conflict, and on the decision to open/close a CWP if it goes above/below a certain value, respectively.

TABLE I. LIST OF SUPERVISOR TOOLS

Tool/Display/System	Definition
Allocation Tool	New tool, specific to FCA. Ensures that all aircraft entering the FCA airspace is assigned to one controller and that the number of aircraft per controller is adequate.
Workload Management Tool	New tool, specific to FCA, provides input to allocation tool. Continually estimates workload levels for each controller, based on parameters such as number of controlled aircraft, number of conflicts, number of aircraft climbing/descending, etc.
Conflict Monitoring Tool	New tool, specific to FCA. Allows the Supervisor to see the conflicts and support the ATCOs.

Tool/Display/System	Definition
CWP Shadowing Tool	Tool to be adapted to FCA. Reproduces the radar display of a specific ATCO in Supervisor screen, as it is or with minor changes. Supervisor should be able to see the ATCO's actions on the screen (i.e., mouse/pointer movements).
Traffic Monitoring (ATM System)	Tool to be adapted to FCA. Provides an overview of the entire flight centric airspace with all traffic. Filtering should be available.
Radiotelephony Shadowing Tool	Allows the Supervisor to listen to voice communications between ATCO and pilots. Tool to be adapted to FCA: given the large area, radio communication is expected to use current radiotelephony systems in association with the position of the aircraft to cover the FCA airspace. See [23] for more information.
Resource Planning Tool	Tool to be adapted to FCA. Supports the Supervisor in charge of the deployment of personnel for the ACC, for roster planning, decide on staffing and manning of controller working positions, etc.
Phone/Voice Coordination Tool	As in current operations, or with minor changes.
Meteorological Information Display	As in current operations, or with minor changes.
Control and Monitoring Display (CMD)	As in current operations, or with minor changes. Provides a user interface to monitor and control the status and operation of various air traffic control components (incl. system diagnostics, error messages, etc.).
Flow Management Position (FMP) Monitor	As in current operations, or with minor changes. Allows the Supervisor to observe changes in traffic flows in order to decide on level capping in coordination with FMP.
Operational Support Data Retrieval	As in current operations, or with minor changes. Provides access to all operational documentation electronically. The information is displayed in a web browser on a dedicated screen next to the radar screen.

2) Traffic Monitoring (ATM System), Conflict Monitoring Tool, CWP Shadowing Tool

Arguably one of the most useful tools for the Supervisor is a display where the entire flight centric airspace traffic is presented. This would allow them to check the location of all conflicts, identify potential hot spots, see all emergency squawks, etc. Filtering and zoom options could also be available to selectively show, for example, all aircraft climbing or descending, only flights crossing or at specific Flight Levels, among other parameters. Given the size of the airspace, this tool would only provide a high level, general overview. For a more detailed view, other tools would need to be available.

As described in the Introduction, in the Flight Centric ATC concept described here, the controllers operated in Single Person Operations, performing the tasks of both the Planner and Executive controllers of a conventional team. Therefore, the four-eyes principle is abandoned and a potential extra safety layer is lost. To mitigate for it, it was suggested that the Supervisor should have the possibility to monitor all conflicts with a look-ahead time of at least five minutes via a Conflict Monitoring Tool. Conflicts could also be displayed via a timeline. Note that the controllers also have a timeline showing all tasks to be performed with a 20-minute look ahead time, and all conflicts detected within that timeframe However, a similar window frame might not necessarily be applicable to the Supervisor, particularly in large FCA airspaces, as there might be too many conflicts. For the Supervisor tasks, a 10-minute look-ahead might be enough and would give the controller at least ten minutes to start acting. Keep in mind though that even 10 minutes might still be too early for the controller to start solving the conflict. The Supervisor might only need to be alerted 5 minutes before, but this value needs to be assessed. Finally, the tool would also give the Supervisor the information which controller is responsible for solving the conflict and the conflict resolution clearance suggested by the system.

Nonetheless, one important point which was further discussed was that an absence of an action by the controllers does not necessarily mean that they are not aware of the conflict. It is possible that for some reason the controller has decided to delay a clearance or is still evaluating the conflict resolution clearance suggested by the system. The Supervisor then has two options: walk to the CWP to observe and, eventually, talk directly to the ATCO (analogous to current operations), or use the CWP Shadowing Tool which would show the radar display of a chosen ATCO in the Supervisor screen, including mouse movements and all open windows. This would allow the Supervisor to confirm the ATCO's awareness of the conflict: is the ATCO currently probing for clearances, sending a text message to the other controller involved in the conflict? Or is the ATCO perhaps busy with a different aircraft and missed the conflict alert? Specific operational procedures would then have to be developed to specify how and under which conditions the Supervisor can intervene.

Arguably, the three tools mentioned above could be part of the same display and/or merged into one, depending on the level of automation and interface requirements. Future studies will be needed to assess these.

3) Remaining Tools

Most of the remaining tools shown in Table I would be used as in current operations or with only minor adaptations to the FCA concept. As in current operations, the Supervisor would be able to listen to specific radio communication between a controller and a pilot via the Radiotelephony Shadowing Tool and they would have their own Phone/Voice System for coordinating purposes. A Meteorological Information Display would also need to be available.

In addition, the Supervisor in charge of manning the control room would have a Resource Planning Tool to decide on staffing and manning of the controller working positions. The Technical Supervisor would also need a Control and Monitoring Display to check the status of the different tools and systems. As in current operations, there might also be an Operational Support Data Retrieval or similar tool to provide access to all relevant operational documentation electronically. Finally, the Flow Management Position Monitor was also mentioned but it was not considered a crucial tool in the flight centric concept (as there are no sectors). Its use might depend on the number and type of Supervisors working concurrently.

IV. Conclusion

This paper summarizes the results of a workshop with air traffic controllers to identify the impact of Flight Centric Air Traffic Control concept on the Supervisor role. The findings reported here are just a first step and further research is needed. In particular, all systems and tools mentioned should either be developed or adapted, and then assessed in a real-time simulation. Prior to that, more specific technical and operational requirements for all systems need to be formalized with support from technical experts. Another very important step will be to identify the level of detail of the information or data that must be shared with the Supervisor, as it is extremely important not to overload them with information that is not relevant. It is thus possible that some of the tools mentioned here could be merged into one and/or some tasks could be further automated.

Not only was the Flight Centric ATC concept of operations new to the ATCOs who participated in this workshop, but the concept assumes much higher automation levels than in current operations. In addition, the planner-executive controller team is replaced with single person operations and several new Supervisor tasks are created or largely modified. Therefore, it is not surprising that participants requested more control over several operating procedures, over the allocation process and more support during conflict resolution than might actually be necessary. As an example, the Workload Management Tool is dynamic and should thus immediately adjust to minor workload asymmetries, emergencies, bad weather, etc. That means it is not clear yet how much tweaking or monitoring of this tool would actually be required, apart from the very specific cases described earlier (e.g., on-the-job training). It is also not clear how often the Allocation Tool would need to be overridden.

It is not surprising that ATCOs suggested the creation of a new role, a back-up person who might be seen as another safety barrier or an extra pair of eyes over the traffic situation. Considering the limited experience that the controllers had with the tools, trust levels were arguably not high and a mental model of the system and its functionalities could not be fully built. Not only that, but the Allocation and the Workload Management Tools were only discussed at a conceptual level, since there is still no interface available (i.e., they are fully automated and do not allow any manual inputs). Notwithstanding, the discussion has allowed us to identify priorities in our research moving forward. Future real-time simulations should include a realistic Supervisor station with at least an allocation tool allowing reallocation and a way to adjust workload thresholds individually. In addition, specific operating procedures should be defined and assessed to handle delays in conflict resolution and the uncertainty of not knowing whether the ATCO is aware of them, in particular when both aircraft are under their control.

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References

[1] B. Birkmeier, B. Korn, and D. Kügler, "Sectorless ATM and advanced SESAR concepts: Complement not contradiction."29th Digital Avionics Systems Conference. IEEE, 2010, doi:10.1109/DASC.2010.5655475.

[2] B. Birkmeier, B. Korn and F. O. Flemisch, "First findings on the controller's mental model in sectorless air traffic management," 2011 IEEE/AIAA 30th Digital Avionics Systems Conference, Seattle, WA, USA, 2011, pp. 6C1-1-6C1-11, doi: 10.1109/DASC.2011.6096100.

[3] T. Finck and B. Korn, "Requirements for an Allocation Center for the Flight Centric Air Traffic Control Concept." Engineering Proceedings 90.1 (2025): 55, doi: 10.3390/engproc2025090055.

[4] P. Gil, A. Vidaller, M. Cano, D. Gómez, J. A. López, N. Cenal, J. Chaves and F. Ruiz-Artaza, "Feasibility and benefits of implementing flight centric ATC in the Spanish upper airspace. " SESAR Innovation Days (SID), Seville, Spain, 2023.

[5] P. Volf, "Comparison of the flight centric and conventional air traffic control." 2019 Integrated Communications, Navigation and Surveillance Conference (ICNS). IEEE, 2019, doi: 10.1109/ICNSURV.2019.8735109.

[6] T. Finck, C.S. Kluenker and M. Weber, ‘’Conceptual Analysis of Allocation Strategies for Air Traffic Control Concepts without Conventional Sector Boundaries’’. 2023 Integrated Communication, Navigation and Surveillance Conference (ICNS), pp. 1-11, IEEE, Herndon, VA, USA, 2023, doi: 10.1109/ICNS58246.2023.10124289.

[7] K. Capiot, A. P. G. Martins, and M. Weber, “Performance Review of Non-Nominal Scenarios in a Validation Exercise of the Flight Centric Air Traffic Control Concept,” in SESAR Innovation Days, 2022.

[8] B. Birkmeier, J. Schmid, A. R. Schmitt and B. Korn, ‘’Change of controller tasks in a sectorless ATM concept-first results’’. In 2012 Integrated Communications, Navigation and Surveillance Conference (pp. I6-1), IEEE, doi: 10.1109/ICNSurv.2012.6218414.

[9] V. Duong, G. Gawinowski, J. Nicolaon, D. Smith, 2001, ‘’Sector-less Air Traffic Management’’, Proceedings of the 4th USA/Europe Air Traffic Management R&D Seminar 2001.

[10] B. Korn, C. Edinger, S. Tittel, D. Kügler, T. Pütz, O. Hassa, B. Mohrhard, ‘’Sectorless ATM — A Concept To Increase En-route Efficiency’’, Proceedings of the 28th Digital Avionics Systems Conference 2009, doi: 10.1109/DASC.2009.5347535.

[11] B. Birkmeier, M. Biella, ‘’Safety Net for a Sectorless Air Traffic Management Concept’’, Proceedings of the 31st Digital Avionics Systems Conference (DASC) 2012, Williamsburg, VA, USA, doi: 10.1109/DASC.2012.6382340.

[12] B. Birkmeier and B. Korn, "Five Transition Strategies for Sectorless ATM." Proceedings of the33rd Digital Avionics Systems Conference (DASC) 2014, doi: 10.1109/DASC.2014.6979410.

[13] B. Birkmeier, S. Tittel and B. Korn, "Controller team possibilities for sectorless air traffic management." 2016 Integrated Communications Navigation and Surveillance (ICNS). IEEE, 2016, doi: 10.1109/ICNSURV.2016.7486362.

[14] A. P .G. Martins, T. Finck, V. Mollwitz, F. Kling and D. Rohacs, ‘’Feasibility study of flight centric mode of operations. A human performance approach’’. 9th SESAR Innovation Days, Athens, 2019.

[15] SESAR2020, D2.3.170 - PJ.10-W2-73 FCA-V3 Final Validation Report (VALR), Ed 01.01.01, 2023.

[16] C.S. Kluenker and T. Finck, ‘’Roadmap towards an ECAC-wide Flight Centric ATC implementation’’. 2023 Integrated Communication, Navigation and Surveillance Conference (ICNS), pp. 1-9, IEEE, Herndon, VA, USA, 2023, doi: 10.1109/ICNS58246.2023.10124327.

[17] C. S. Kluenker, M. Weber, T. Finck and A. Taraldsson, “Effects on ATCO Training when Working in a Flight Centric ATC Environment”, 2023 IEEE/AIAA 42nd Digital Avionics Systems Conference (DASC), Barcelona, Spain, 2023, doi: 10.1109/DASC58513.2023.10311161.

[18] C. S. Kluenker, K. Krueger, and T. Finck, "Assessing a Radar Display Concept for Large Flight Centric ATC Airspaces," 2024 Integrated Communications, Navigation and Surveillance Conference (ICNS), Herndon, VA, USA, 2024, pp. 1-8, doi: 10.1109/ICNS60906.2024.10550700.

[19] M. Weber, A. P. G. Martins, C. Erdinger, and C.S. Kluenker, “Air-Ground Datalink Technologies (LDACS and current CPDLC) in Flight Centric ATC: Analysis of a Fast-Time Simulation and Outlook on a Complementary Real-Time Simulation,” 43rd Digital Avionics Systems Conference (DASC), San Diego, 2024, doi: 10.1109/DASC62030.2024.10749441.

[20] A. P. G. Martins, C. S. Kluenker, C. Edinger, S. Tittel and M. Weber, "Evaluation of the Impact on Air Traffic Controllers of Air-Ground Datalink Technologies (LDACS and current CPDLC) in Flight Centric ATC." In 2024 AIAA DATC/IEEE 43rd Digital Avionics Systems Conference (DASC) (pp. 1-9), IEEE, doi: 10.1109/DASC62030.2024.10749213.

[21] “Welcome to the eATM Portal”, [online], URL: https://atmmasterplan.eu/, [Retrieved 28 April 2025].

[22] C. S. Kluenker, M. Weber, T. Finck and Å. Taraldsson, "Effects on ATCO Training when Working in a Flight Centric ATC Environment," 2023 IEEE/AIAA 42nd Digital Avionics Systems Conference (DASC), Barcelona, Spain, 2023, pp. 1-9, doi: 10.1109/DASC58513.2023.10311161.

[23] SESAR2020 PJ.10-W2-73, D2.3.030 – PJ.10-W2-73 FCA-V3 Final SPR-INTEROP/OSED Part I – V, 31/03/23, 01.00.00.

[24] DES HE SESAR FCA, D2.8 – Intermediate SPR-INTEROP/OSED for 2nd TPRM, 09/03/25, 01.00, unpublished.

[25] Finck, T., Kluenker, C., & Martins, A. P. G., "Validation of the Flight Centric ATC Concept using Hungarian Airspace as an Example." AIAA 2023-3259. AIAA AVIATION 2023 Forum. June 2023. doi: 10.2514/6.2023-3259.

[26] K. Capiot, B. Korn, A. Papenfuss and M. Mulder, "Evaluation of Controller Position Takeover in Team-Based Flight Centric ATM. " In 2021 IEEE/AIAA 40th Digital Avionics Systems Conference (DASC) (pp. 1-7), IEEE, doi: 10.1109/DASC52595.2021.9594486.

[27] L. J. Materne and M. Friedrich, "Supervision of Multiple Remote Tower Centers: Evaluating a New Air Traffic Control Interface Based on Mental Workload and Eye Tracking." IEEE Transactions on Human-Machine Systems (2025), doi: 10.1109/THMS.2025.3527136.