Flexible Airspace Management Operator Roles, Task Distribution, and Coordination Mechanisms

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A human-in-the-loop study was conducted to further test the potential benefits of the Flexible Airspace Management concept and to begin exploring the required coordination aspects of the concept. The air navigation service providers were able to dynamically alter sector boundaries to reduce traffic overload, thereby potentially increasing airspace utilization, increasing route efficiency, and minimizing excessive delays. Although prior studies have shown benefits of the concept, the operational procedures have yet to be sufficiently prototyped. To address this issue, the current study investigated the roles, task distribution, and coordination mechanisms involved in Flexible Airspace Management operations, specifically in regard to the Area Supervisor and the Traffic Management Coordinator positions. Results suggest that sharing the airspace management function between the Area Supervisors and Traffic Management Coordinators was appropriate and worked well when their roles were clearly defined and the Traffic Management Coordinators had the final authority for implementing the airspace configuration change. New data communication functions were prototyped to share airspace configuration proposals among the team members and the new functions were considered highly useful and usable. Coordination mechanisms that combined voice and data communication worked well and posed little difficulty to the operators.

INTRODUCTION

The National Airspace System (NAS) has a finite capacity for air traffic which must be managed by Air Navigation Service Providers (ANSPs). The traffic demand often exceeds the airspace capacity, leading to costly and time consuming flight delays. Future traffic demand is expected to rise, further exacerbating the problem (Kopardekar et al., 2009).

As a part of the solution, the Federal Aviation Administration (FAA) has proposed a mid-term concept called Flexible Airspace Management (FAM) for the Next Generation Air Transportation System. The purpose of FAM is to support the Air Navigation Service Provider (ANSP) with the ability to proactively manage air traffic by means of flexibly changing airspace configurations to meet the needs of the forecasted traffic demand during that shift. In contrast, current-day airspace reconfigurations alter sector boundaries by combining and splitting existing sector boundaries. The current sector combination and splitting is performed by the Area Supervisor either as a reaction to the current traffic situations in the Area or as a result of a large, predictable demand change, such as the one that occurs during the midnight shift (Taber, N.J., Woodward, F., and Small, D., 2000).

By reconfiguring the airspace proactively, the FAM concept aims to better utilize the airspace to achieve higher throughput, to reroute fewer aircraft, and to provide more efficient routes.

In 2009, the FAA and NASA conducted a human-in-the-loop (HITL) simulation to examine the impact of airspace configuration changes on air traffic controllers (Homola et al., 2010). The study prototyped and assessed the roles, responsibilities, tools, and procedures for the controllers and their interactions with the Area Supervisor. The results suggested that the operation in the Area was feasible and provided a good framework for the tools and procedures. However, the role of the “airspace planners” who would assess the airspace configuration options and implement the new configurations have yet to be identified and the larger impact of FAM on other team members was still unknown. In the current study, the overall team configuration and the roles of each operator were defined and evaluated for both planning and implementation of airspace reconfigurations. The following sections describe the study more in detail.

Current Study

The focus of the study was to prototype an operational framework for FAM planning and implementation. The FAM operation was envisioned to be a component of traffic flow management, and therefore included Traffic Management Coordinator

(TMC) and Supervisor TMC (STMC) positions for flow planning and airspace reconfiguration purposes. Area Supervisors were also tasked with airspace reconfiguration duties in addition to working with controllers to implement the configuration changes. As the roles and task distribution were assigned to the operators and the coordination procedures were developed, the following questions emerged.

Roles and task distribution:

- Which operators should propose and implement boundary changes?
- What is the timeframe outlook of each team member when performing FAM tasks?

Coordination:

- Are the Area Supervisors and TMCs able to plan and coordinate FAM ideas by voice communication?
- Can the operators share/coordinate boundary changes with decision support tools successfully?

This paper will focus on the operator roles and coordination procedures of the two main FAM positions -- TMCs and Area Supervisors. The overall findings can be found in the report by Lee et al. (2011).

METHOD

Participants

Three active Front Line Managers from the FAA and one recently retired controller, each with experience as Traffic Management Coordinator (TMC) and/or Area Supervisor, were recruited as test participants. The participants who staffed the planning positions of Area Supervisor and TMC were referred to as the "planning team." In addition to the four test participants, twenty confederate participants were recruited for various support positions (radar controllers, "ghost" TMCs, and simulation pilots).

Environment

The environment was simulated using the Multi Aircraft Control System (MACS), a platform specifically built for mid- to high-fidelity air traffic control simulations (Prevot et. al., 2006). Three rooms were set up to reflect one Traffic Management Unit (TMU) and two Areas of Specialization within a facility. Other rooms were used for simulation pilots and confederate controllers who managed the surrounding airspace.

The operational environment was mid-term high-altitude en route airspace at FL340 and above. The airspace was assumed to have full data communications (Data Comm) equipage for all aircraft occupying the airspace, as well as automated conflict detection and resolution capabilities in the ground-air traffic system, ground-ground data coordination capabilities with real-time interactive exchanges of trajectory and airspace management plans between the ground stations, and decision support tools that enabled air traffic operators to view the predicted traffic situation and modify either the airspace or aircraft trajectories when needed. The operators were able to select from pre-defined airspace configurations generated by algorithms, which are described in Zelinski (2009).

The test airspace consisted of either four sectors or seven sectors in Kansas City Center (ZKC). Traffic scenarios were created to simulate traffic deviations and congestion caused by large convective weather cells. The resulting traffic imbalance necessitated aircraft reroutes and/or airspace reconfiguration.

Experiment Design

The study was a 2x2 within-subjects design with two factors: the boundary change condition **(**BC or No BC**)** and the number of sectors involved in the reconfiguration (4-sector or **7-**sector). The BC condition included FAM, whereas No BC was the baseline without FAM. The use of four or seven sectors was intended to test small and large airspace reconfigurations, respectively. There were a total of 8 data collection runs for the 4-sector problems and 4 data collection runs for the 7-sector problems, for a total of 12 data collection runs. The 6 boundary change runs were analyzed for this report.

Operational Procedure

The study was in part an attempt to define the roles and procedures of the TMCs and Area Supervisors performing FAM. Therefore, the participants were provided with decision support tools and instructed to resolve sector oversaturation through FAM (in the BC condition) and subsequent reroutes in order to maintain a threshold of 22 aircraft or lower per sector while determining their own roles and procedures for the task. Figure 1 illustrates the workstation of the TMCs and Area Supervisors.

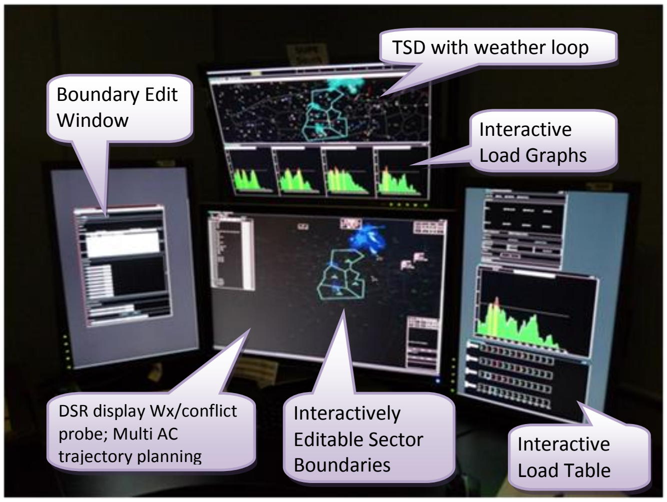

Figure 1: Planner station interactive display with decision support tools.

In the study, TMCs and Area Supervisors needed to analyze the traffic and airspace situation, choose one of eight possible boundary reconfigurations, plan their course of action, coordinate and agree upon a solution with the other TMCs and/or Area Supervisors, and execute the plan together.

Although the planning task of the airspace reconfiguration was shared by Area Supervisors, TMC, and STMC, they were instructed to focus on different temporal and spatial domains. Area Supervisors were asked to focus on airspace within the Area and traffic within a 30 minute time horizon. The TMC and STMC were asked to focus on the whole facility and traffic outside of the 30 minute time horizon. The STMC had the added role of being the central coordinator. Because each team member could reconfigure the airspace, participants were allowed to explore who could propose and decide on the final airspace configuration.

During the boundary reconfiguration selection process, either an Area Supervisor or a TMC proposed a new airspace configuration and coordinated it with the other operators. Proposed configurations were shared using the Boundary Edit Window via ground-ground data coordination and discussed over the voice communication system. The Boundary Edit Window allowed the operators to analyze, select, and share the new airspace designs with the other operators. Traffic flow changes were also planned by the planning team and sent to the controllers via ground-ground data coordination.

In the 4-sector problem, two test participants were staffed as Area Supervisor and TMC along with four retired controllers to work the radar scopes. In the 7-sector traffic problems, the seven test sectors were divided into North and South Areas with retired controllers staffing the sector positions and test participants staffing the Area Supervisor positions. Two test participants with TMU experience alternated by run between the TMC and STMC position for Kansas City Center (ZKC). The STMC assumed the central coordinator role when communicating with the Area Supervisors and the TMUs from the other facilities (i.e., confederate “ghost” TMC).

The communication flow diagram for the 7-sector scenario is shown in Figure 2. The weight of the arrows represents the communication frequency between the positions found in the study. The STMC to TMC had the most discussions, followed by the STMC to both Area Supervisors and the North Area Supervisor to South Area Supervisor. Although the TMC had the ability to call the Area Supervisors directly, he chose to contact the Area Supervisors through the STMC. Voice calls to confederate stations are shown with a dotted line and were not included in the analysis. The 4-sector scenario had a smaller channel of communication that included a TMC, Area Supervisor, TMC Ghost, controllers, and pilots.

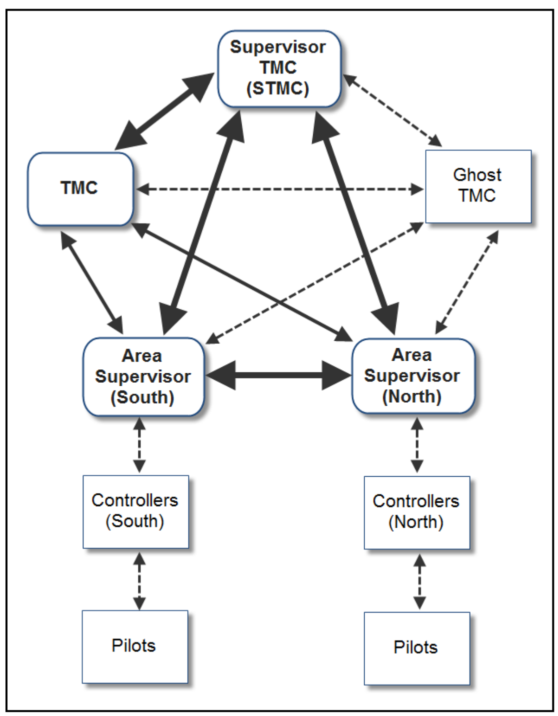

Figure 2: The 7-sector communication path. Heavier lines represent more voice communication and solid lines represent participant-to-participant voice communication.

At the end of each simulation run, the participants were given questionnaires related to the acceptability of their roles, traffic situations, and coordination mechanisms. When the simulation was finished, they were asked additional questions related to the coordination and communication procedures.

RESULTS

The following results are presented in two sections, titled "Roles and Task Distribution" and "Coordination." The sections describe the new functions and interactions for Area Supervisors, TMC, and STMC within the mid-term FAM concept.

Roles and Task Distribution

Proposal and implementation of boundary changes

All of the planner positions were provided with the tools to propose and/or implement boundary changes. Participants were asked to state who initially proposed and decided upon airspace configuration changes. Figure 3 shows the participant reported percentages of the team member who proposed an airspace configuration option and who decided upon the airspace configuration that was to be implemented. Overall, both Area Supervisors and TMCs (including STMC) proposed and decided upon airspace configuration changes but the TMCs played the leading role in both the initial proposal and the final decision. Overall, the results suggest that a collaborative effort with the Area Supervisors was useful for the TMCs to make the final decision on implementing the boundary changes.

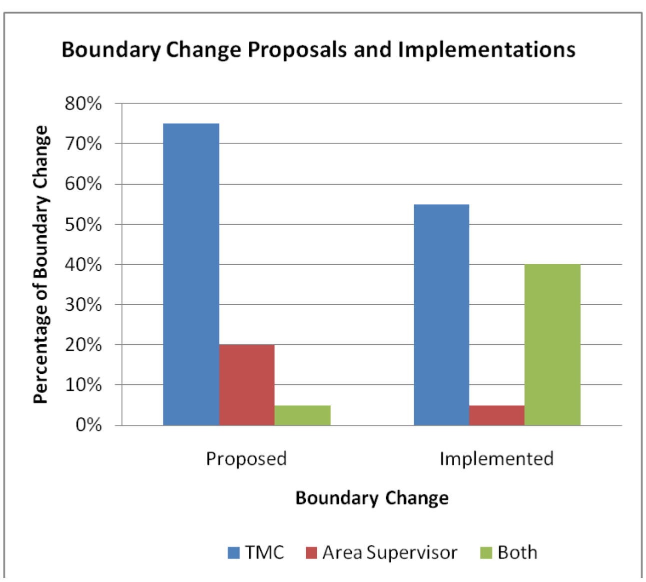

Figure 3: Reported percentage of initially proposing boundary changes and final decision implementation of boundary changes for the planner positions.

Look-ahead Time to Capacity Overload

Participants were asked how far they looked ahead in anticipating and planning for the capacity overload problem (Figure 4). In line with the differing temporal scope of their roles, Area Supervisors tended to focus on capacity problems that were closer in time (mode = 30 minutes away) than did the TMCs (mode = 45 minutes), although this difference was only marginally significant (using the categories "30 minutes" and ">30 minutes", $\chi^2(1) = 3.35$, $p < 0.10$).

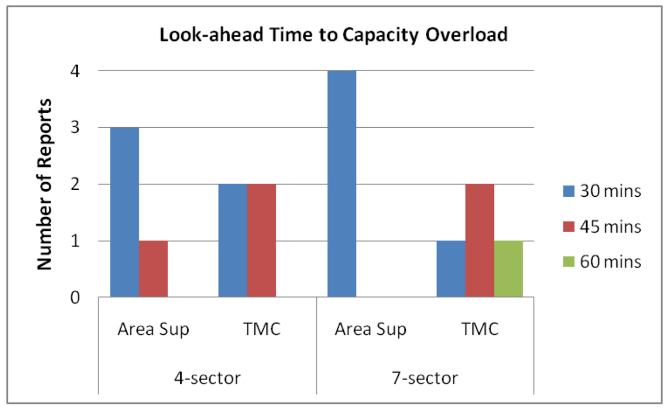

Figure 4: Reports of the look-ahead time to capacity overload.

Coordination

The coordination procedures for airspace reconfiguration were developed by prototyping new mechanisms for the ground-ground data communication that allowed the airspace proposals to be shared among the planning team members and previewed on the controller stations when it was ready to be implemented. The data communications were also accompanied by voice communication between the Area Supervisors and STMC during the airspace proposal stage. The results of both types of communication are described below.

Voice Communication

A post-simulation questionnaire was used to gather insights related to the process of selecting from a set of airspace configuration options and implementing them in coordination with the other planning team members. The rating scale was from 1 ("Very easy") to 6 ("Very difficult"). Overall, the results suggest that the process of coordinating the airspace changes and traffic reroutes was "easy" to "moderate" in difficulty.

The participants rated the difficulty of coordinating traffic reroutes with other positions as "easy." The TMCs coordination ratings (M = 1.50, SD

= 0.53) was not significantly different than the Area Supervisors (M = 2.20, SD = 1.23; t(18) = 1.66, $p > 0.05$).

The participants also rated the coordination of airspace reconfiguration between TMC and Area Supervisor as "easy." The TMCs ratings (M = 1.75, SD = 0.96) were not significantly different than the Area Supervisors (M = 1.50, SD = 0.84; t(8) = 0.43, $p > 0.05$).

Sharing Boundary Proposals via Ground-Ground Data Coordination

The boundary changes were initially proposed by either a TMC or Area Supervisor and shared with the other planners via ground-ground data coordination using the Boundary Editing Window. In the post-simulation questionnaire, the participants rated the usefulness and usability of the Boundary Editing Window and the sharing function within it. The usefulness scale was from 1 ("Not Useful") to 7 ("Very Useful"), and the usability scale was from 1 ("Not Usable") to 7 ("Very Usable").

The overall usefulness of the Boundary Edit Window ratings were high for both TMC (M = 6.50, SD = 0.71) and Area Supervisors (M = 7.00, SD = 0.00). The Area Supervisors (M = 7.00, SD = 0.00) rated the overall usability of the Boundary Edit Window higher than the TMCs (M = 5.50, SD = 2.12).

The usefulness of the sharing function was rated highly for both TMCs (M = 6.50, SD = 0.71) and Area Supervisors (M = 6.50, SD = 0.71). The usability of the sharing function was also highly rated for both TMCs (M = 6.50, SD = 0.71) and Area Supervisors (M = 7.00, SD = 0.00).

DISCUSSION

Functionality for the FAM concept such as changing airspace boundaries and sharing them with other operators were not fully developed prior to this study. The operational procedures for the roles, responsibilities, and coordination were developed in this study for TMCs and Area Supervisors to test FAM operations.

A new function to share airspace designs and coordinate planned airspace changes was evaluated. The results suggest that coordination among the planning team (i.e., Area Supervisors and TMCs) worked well in the mid-term en route environment. The TMCs' knowledge of airspace and traffic flows facilitated the process of proposing and implementing boundary changes to work better under their leadership. They naturally took authority over the process with final decision making authority while the Area Supervisors provided valuable input for local Areas. The ability to discuss boundary changes over voice communication and to share them over ground-ground data coordination between positions was rated as being highly useful and usable with low difficulty ratings.

In conclusion, a framework for FAM operations has been developed to provide appropriate roles and coordination procedures for TMCs and Area Supervisors. Although the framework was evaluated for high altitude en route airspace with full Data Comm equipage, similar procedures are likely to extend to other types of airspace. Further research is needed to identify potential gaps in the procedures as they expand to other traffic situations and airspaces.

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