Feasibility of an Air Traffic Control multi-sector planner position from a user's perspective

Lynne Martin
Tom Prevôt
Paul Lee
SJSUF[1] @ NASA ARC
Moffett Field, CA, USA
lmartin@mail.arc.nasa.gov
tprevot@mail.arc.nasa.gov
plee@mail.arc.nasa.gov

Kevin Corker
Eromi Guteratne
San Jose State University
San Jose, CA, USA
kevin.corker@sjsu.edu
eromi_g@yahoo.com

Nancy Smith
NASA ARC
Moffett Field, CA, USA
Nancy.M.Smith-1@nasa.gov

Teams have traditionally performed Air Traffic Control (ATC) in the United States (US) en route airspace environment. The 'front line' teams are composed of two people who control a sector. These dyads divide duties, with the radar-controller (R-side) having primary responsibility for observing the radar screen and exercising ATC through radio communication with flight crews. The radar-associate (D-side) has primary responsibility for managing flight progress strips and serving as a strategic aide to the radar controller. Each member of the team has many other duties, including coordination with adjacent sectors and maintenance of common situation awareness. Both are responsible for safe, orderly, and expeditious flight progress of traffic in and around their area of responsibility.

Several developments in the technology supporting Air Traffic Management (ATM), e.g., digital data communication, improved positioning accuracy for flight operations, conflict prediction, and sector complexity assessment, have enabled consideration of alternatives to the standard team concept (of a co-located twosome). With more powerful tools, the controller workforce could focus on control decisions and meet the predicted increase in traffic demand without an increase in workforce. Thus, new organizational and functional operations are being considered both in the US and in Europe.

In the present study, the standard dyad configuration was modified to include a "Multi-Sector Planner" (MSP) position in a larger team, who shared his/her controller responsibilities across three abutting sectors. In one concept variation, termed "Multi-D" (MD), the MSP took the traditional role of a radar-associate but provided these types of services to three radar controllers aided by advanced tools. In a second configuration, termed "Area Flow Manager" (AF), the MSP served functions often associated with traffic flow management. The AF role included coordinating with adjacent MSP areas and proactively managing three sectors' traffic levels, again aided by advanced tools. The feasibility and effectiveness of these two concept variations were investigated.

Different conceptualizations of the MSP position have been investigated in several research and field studies (e.g., Eurocontrol, 1997; Thompson & Viets, 2000). The Multi-D concept evaluated in the present study is in line with the PHARE concept B (Marsh, 2001) and with the Herr, Teichmann, Poppe, & Suarez GATE-TO-GATE MSP configuration (2005). However, the implementation approach differs in both the procedures and tools available to the MSP (see a concept comparison in Choo, et al., 2004). The MSP as a traffic flow controller – the second concept in the present study – is more in line with Eurocontrol's Concept A (Marsh, 2001), expanded by Guizavu (2002). It becomes apparent that the multi-sector planner concept provides opportunities for a spectrum of redistributed roles and responsibilities among ATM team members.

Reorganizing a team, despite its goals and task set remaining the same, changes the dynamics of how the members work together, i.e., how they communicate and coordinate. In our study, team dynamics were a key consideration in the concept feasibility assessment. The study was designed to give controllers an equivalent set of advanced tools in all conditions. By doing this, the focus of the results was on the within-team shift in roles and

[1] SJSUF is the San Jose State University Foundation; ARC is the Ames Research Center

responsibilities that resulted from the MSP concepts and how this changed team processes such as coordination and communication.

Study design and method

Participants. Ten Air Traffic Supervisors and Traffic Managers from US ARTCCs (Air Route Traffic Control Centers) participated in the study, five in the first week and five in the second. In each week, three participants were assigned to a radar controller position and remained in it for the week. Two participants were assigned to the MSP and radar associate positions and alternated, which they worked based on the study condition.

Scenarios. The airspace of interest was a modified representation of three sectors from the north of Fort Worth Center (ZFW) airspace (Figure 1). Two different high traffic scenarios were designed specifically to exercise different facets of the MSP's roles and responsibilities. Each scenario was an hour long and traffic peaked above the recommended sector loading for one controller at some point in each of the three sectors. A weather condition that could overlay both scenarios was added, and the traffic levels were slightly reduced in each sector to compensate for the weather load.

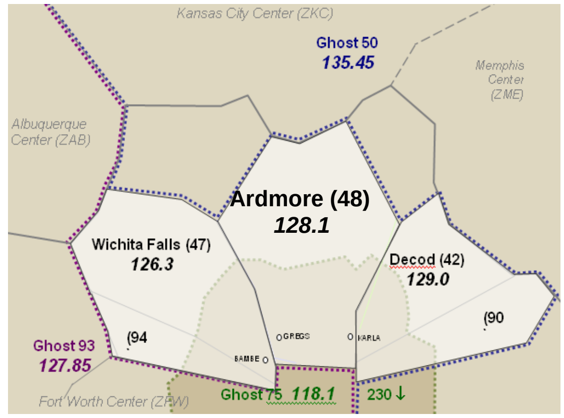

Figure 1. Modified test sectors in ZFW airspace

Study conditions. Three conditions were studied – a baseline, a Multi-D (MD) MSP team, and an Area Flow (AF) MSP team, each of which were provided with advanced decision support tools and electronic flight strips.

Baseline. The five-person controller team was comprised of three R-sides (one for each sector) and two D-sides, who supported the R-sides in the busiest two sectors and were seated beside them. Although the procedures and the roles for the participants were similar to the current day, the tools and the workstation layout were enhanced. Participants had access to a number of advanced tools including air-to-ground data link (CPDLC), trial planning (TP), and conflict detection. A pilot-controller and controller-controller voice communications system was also provided.

Multi-D MSP team. The four-person controller team was comprised of three R-sides and one Multi-D, who performed the D-side function for all three R-sides, aided by enhanced tools. In addition to CPDLC, trial planning and conflict detection, the MD had load graphs of each sector and a separate display that could repeat each sector, as s/he sat at a separate console from the R-sides. The MD role was to support the R-sides by "managing traffic flows within the multi-sectors and providing medium-term conflict resolutions" (Corker, et al., 2006, p8). Procedures varied from the baseline in two ways – the MD no longer had to deal with handoffs and was not tasked with double-checking R-side computer entries. The fifth controller assisted as a confederate controller for the adjacent sectors.

Area Flow MSP team. The four-person controller team was comprised of three R-sides and one Area Flow, whose task was to assume responsibility for managing traffic flows and balancing traffic loads within the multi-sector area. In taking on this traffic flow role, AF positions did not have procedural responsibility for tasks dealing with individual aircraft (e.g., handoffs, short-term conflict detection) and did not have a direct communication link to aircraft. S/he was also located in a separate room. AF positions were provided with the same tools as the MD with the exception of conflict detection. Again, the fifth controller assisted as a confederate.

Study procedures. Each controller group completed ten study runs – five in the baseline condition and five in either the Multi-D condition (week 1) or the Area Flow condition (week 2). Scenarios were balanced across the conditions, but the focal interest was controller responses to, and opinion of, the MSP conditions rather than the scenario variables. Participants were asked to manage the traffic to achieve the same levels of separation and traffic flow that they would strive for when they are on-position at their ARTCC.

During the study runs, each participant was observed by one of the research team, who noted key actions and interactions and voice communications were recorded. The simulation system logged every interaction the participants made through the tools and all aircraft performance histories were collected. Immediately after each study run, participants completed an adapted Cooper-Harper rating scale (Lee, Kerns, Bone & Nickelson, 2001) (CARS). At the end of the simulation week, participants completed a 44-item questionnaire about their role in the study conditions. The role questionnaire was divided into nine topics covering areas such as coordination, working method, communication, and procedures.

Data analysis. The feasibility and operational benefits of the two MSP concepts were investigated first by comparing within-subject performance data, i.e., performance of subject participants operating under each MSP condition were compared against performance of the same participants in the baseline. These within-subject analyses examined the relative benefits and shortcomings of each MSP concept compared to the standard R and D controller team without potential confounds due to individual differences.

Analyses of the objective data and wider study considerations are reported in Corker, et al. (2006), along with a detailed review of the team dynamics data presented here. Given the small number of participants and study runs, only descriptive analyses were appropriate for most of the team process data. Exceptions are the tool interaction/task event list recorded by the simulation system and the CARS. Not all of the data collected could be presented in this short paper; the CARS, role questionnaire and simulation events were selected to give an overview of the study findings to date.

Results and discussion

Broad study findings. A brief summary of the objective data analysis provides a frame for the team dynamics analyses below. Traffic management analyses indicated that MSP team configurations managed the traffic more strategically (see Corker, et al., 2006). For example, conflicts were resolved earlier under MD, compared to baseline, conditions for no-weather scenarios, and AF controllers used fewer tactical maneuvers in weather scenarios compared to the baseline. There were no significant reductions in overall workload, but workload was distributed more evenly across the controller team, giving a better balance between MSP and R-side workload than D- vs. R-side load. Participants judged the advanced tools to be usable, useful, and helpful, although there was no lack of suggestions for additional tools and features (see Prevôt, et al., 2006).

Focusing from this onto the team perspective, analyses of the subjective participant responses indicate that participant experience of the Multi-Sector controller teams varied not only with the role that the MSP took (as expected) but also with their position on the team – R-side versus MSP.

Communication. An objective measure of participants' communication load is the number of messages they send to another controller or a pilot. In the analysis presented, the number of trial plans (TP) sent by the MSP/D-side positions and their associated clearances are compared to participants' subjective responses.

Multi-D communication. Figure 2 (first pair of bars) illustrates that the average number of messages sent by the MD or MD-D-side participants are fewer in the Multi-D condition than in the baseline. MD opinions described this for their communications in general – they felt they communicated 'more than usual' in the baseline (M=3.5)[2] but not in the MD condition (M=3). R-sides also felt they communicated less under MSP conditions (M=2.3) but more in baseline conditions (M=3.6); one controller's reasoning for this was:

---

[2] Unless otherwise specified, ratings were made on a Likert-type scale where 1 was a positive rating and 5 was a negative rating. A rating of 3 represented usual or no change.

"many routes already done, requiring less coordination from me to [other sectors] or ghosts for control instructions." Most, but not all, of the Multi-D participants thought the methods of communication available to them were sufficient, but the physical location of R-sides and MD at different stations was mentioned as a hurdle: "the further the MSP is from the controller, the more difficult."

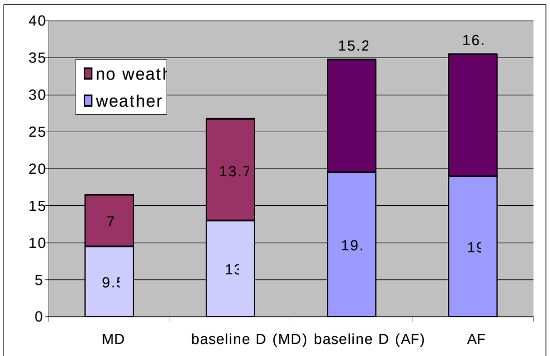

Figure 2. Mean number of trial plan messages s

Area Flow communication. Figure 2 shows the average number of AF TP coordinations in the second pair of bars; these are similar across the AF and baseline conditions. AF opinions of their communication supported this – they reported they communicated 'a lot' in both conditions (M=4.5 & 5). Comparing the AF's messages to those of a confederate AF, who was manning the sectors adjacent to the ZFW sectors, showed the confederate sent very few messages (M=0.5) when there was no weather but almost as many as the AF (M=15.5) in weather scenarios. From this, it seems the AF relied more heavily on coordination with outside sectors to manage traffic when there was weather in his sectors. Data link was the preferred method of communication for the area flow teams, who said, "voice comms is [sic] too time consuming and distracting."

As the averages of the TP messages sent in the baseline conditions showed different trends for the two weeks, it implies these may be affected by individual differences and, therefore, the MSP conditions were not directly compared. An issue raised by both teams was whether the methods of communication were sufficient, but they suggested opposite ways to solve this problem. AF suggested moving to less verbal communication (using more data link), which was, in part, due to AF being in a separate workspace from the R-side controllers and that their tasks required less coupling than MD. In contrast, MD suggested co-location of team members and direct voice communication, again partly due to the nature of their tasks (e.g. conflict resolution inside the sector) and the room configuration.

Coordination. Team coordination was measured through the number of TP coordinations initiated by participants, and queried through ratings and solicited comments.

Multi-D coordination. MD initiated fewer TP coordinations, on average, than they did as D-sides in the baseline, particularly in no-weather scenarios (Figure 3). Team opinions of their general coordination were contradictory: participants in all positions, except the MD, reported that they found coordination 'reasonably easy' to maintain (means ranged from 2.2 to 2.8 on a seven point scale, SD range was 1.7-2.1). MD reported that they found coordination 'a little difficult' (M=4.4, SD=1.9). This difference was not significant.

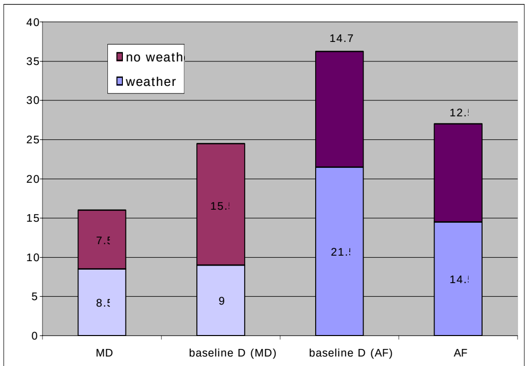

Figure 3. Mean number of trial plan coordinations positions

Questionnaire responses supported a difference of opinion. MD said they spent the 'right amount' of time coordinating with the other controllers (M=3), while R-sides thought they spent 'too little' time (M=1.6). MD reported they sometimes had difficulties coordinating (M=3) whilst R-sides reported 'few difficulties' coordinating when they wanted (M=2.3). R-sides reported uncertainty over what coordination to expect: "with MSP actions, I did not know what for" but so did MD: "minimal coordination from the radar person to the MS prompted internal concerns." The impression given is that R-sides were unsure when to ask for help, and MD were unsure when to offer it.

Area Flow coordination. Figure 3 shows that the average TP coordinations were fewer for the AF than for the baseline team. All participants rated their team coordination as 'quite easy' to 'easy' (means range from 1.4 to 2.4 on a seven-point scale). Questionnaire responses also supported that the AF team found few problems with their coordination and teamwork and, if anything, advocated trying to reduce verbal coordination further between team members. An AF said, "MSP should not call R-side directly – distracting." Despite being generally happy with the coordination, R-sides and AF differed on the amount of time they felt they spent coordinating – AF said they spent 'a lot of time' (M=4), but R sides said they spent 'too little' (M=2). In at least one case, R-sides took responsibility on themselves for the lack of coordination they perceived: "I realize I should have requested help."

As the baseline coordination activity averages showed different trends for the two weeks, it again implies these may be affected by individual differences and the MSP conditions were not directly compared. A factor that could have been raised by both teams as a hurdle to coordination was their seating arrangements. However, only the Multi-D teams saw it as an issue. Despite the repeated sector displays, MD commented, because they could not directly observe the actions in a specific sector, this "impacted the ability to identify when it would be appropriate to call in for coordination." AF were not concerned about co-location: "wasn't a factor – if comms are automated, the MSP could be anywhere."

***Concept roles and responsibilities*.** Participants rated the acceptability of their position through the CARS (Lee, et al. 2001). It is completed as a flow chart that, after adaptation, led to participants giving a rating (on a 10-point scale) of the acceptability of their position.

Multi-D role. Figure 4 shows the average CARS ratings for MSP/D-side participants. MDs rated their positions less highly than their MSP and baseline teams, although they did find the MD position more acceptable than the D-side position. A univariate ANOVA was used to compare the effects of Condition (baseline vs. MD) and Role (D vs. R). It showed a significant difference in ratings between R and D sides (F=12.79, df=1, p=0.001) indicating that R-sides found their position on the team more acceptable. The lowest mean rating (of 5.9) was given by D-sides – a six on the CARS is described as "Moderate deficiencies. Adequate performance was achieved with considerable work-arounds to adequately manage the traffic." The MD rating, at a mean of 6.6, has the same description. Expanding on their opinions in open-ended questionnaire responses, participants reported that the MD position has benefits, e.g., identifying dynamic route structures, but will change the nature of the controller team. The extent of this change may require a long adjustment process, as it affects positions' responsibilities. The beginning of this adjustment was observed, as the work-arounds described included participants using the tools provided with new methods.

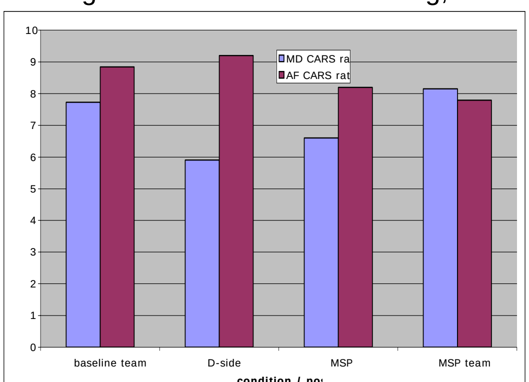

Figure 4. Mean CARS ratings for AF and MD tea

Area Flow role. AF rated their MSP positions more highly than their MSP team (Figure 4) and also rated their D-side positions more highly than their baseline team. The AF team gave similar ratings to their positions' acceptability and rated them as slightly less acceptable than the familiar baseline condition. Their ratings hover around the CARS 8^{th} point, which is described as "Mildly unpleasant deficiencies. Position was acceptable and minimal work-arounds were needed to meet desired performance effectiveness." These rating differences were not significant when tested through a univariate ANOVA.

The open-ended questions gave participants an opportunity to comment on the AF concept. AF controllers liked the bigger picture that the concept facilitated and that they could view the problem strategically. However, R-sides expressed some confusion over their role within the AF team: “who? why? when? My rights and responsibilities as an R-side to accept, deny, or even modify an MSP plan.” This reaction may, in part, be due to the study intentionally leaving roles open to be interpreted.

The CARS baseline ratings were significantly different between the two D-side groups. It implies these averages are affected by individual differences and hence conditions were not directly compared. However, both groups raised the same two issues – concerns about the extent of changes that moving to an MSP team will entail and the need to create trust between the positions.

Conclusions

The study showed the feasibility of both concepts and, in general, that teams reconfigured with a MSP can be effective. Given the considerable change in team organization and procedures, controllers were able to work well together under both concepts. Possible benefits, such as a reduction in coordination activities, under the MSP were highlighted. However, there were some areas where participant experiences differed, indicating that the two variations of the concept tested were not equivalent. For example, the AF team accepted their new configuration and advocated complementary procedural changes (more data link and less voice), while MDs preferred to revert to the standard configuration. All participants felt the concepts need refining but Multi-D were the least happy with their position. However, as MD gave lower ratings to their baseline position also, this is possibly confounded by individual differences.

Acknowledgements

We would like to thank the FAA sponsors, specifically Diana Liang and Richard Jehlen; Dean Fulmer of the FAA, and the observers from MITRE, Eurocontrol, and ISA. We owe special thanks to the FAA study participants for their valuable feedback and suggestions.

References

Choo, L., Corker, K., Garcia-Chico, J., Guneratne, E., Howard, M., Tang, A., & Verma, S. (2004). *Multi-Sector Planner Position: Cognitive Work Analysis.* Unpublished Manuscript.

Corker, K., Lee, P., Prevôt, T., Guneratne, E., Martin, L., Smith, N., Verma, S., Homala, J., & Mercer, J. (2006). *Analysis of Multi-Sector Planner Concepts in US Airspace*. Report for the FAA. San Jose, CA: San Jose State University.

Eurocontrol (1997). PHARE: En route Multi Sector Planning Procedures. PD/3 IOCP Programme, PHARE/EEC/PD3-3.1.3.2.5/SSR;01.

Guizavu, A. (2002). *MSP Operational Concept and TFM* (Version 0.2). Brussels Belgium: Eurocontrol International.

Herr, S., Teichmann, M., Poppe, M., & Suarez, N. (2005). The impact of multi sector planning and new working procedures on controller tasks. Proceedings of the *24th Digital Avionics Systems Conference (DASC 2005)*.

Lee, K., Kerns, K., Bone, R., & Nickelson, M. (2001). Development and validation of the controller acceptance rating scale (CARS): Results of empirical research. Proceedings of the *4th USA/Europe Air Traffic Management R&D Seminar*, Santa Fe, NM, December 3rd–7th.

Marsh, D. (2001). *Clarification of Concepts for Multi Sector Planning,* (Final Report TRS98/2K). Eurocontrol Experimental Centre. Bretigny, France.

Prevôt, T., Lee, P., Martin, L., Mercer, J., Palmer, E., & Smith, N. (2006). Tools for trajectory-based Air Traffic Control and Multi Sector Planning. To be presented at *HCI Aero*, September, 2006.

Thompson, K. & Viets, K. (2000). Layered strategic planning in the En Route National Airspace System (NAS): Air Route Traffic Control Center (ARTCC) Perspective. MTR 00W0000064, August, DTFA01-93-C-00001. McLean, VA: Mitre.