Ground-Ground Data Communication-Assisted Verbal Communication for Multi-Sector Air Traffic Management

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A human-in-the-loop simulation was conducted to investigate the operational feasibility, technical requirements, and potential improvement in airspace efficiency of adding a Multi-Sector Planner position to air traffic management. A subset of the data from that simulation is analyzed here to determine the impact, if any, of ground-ground data communication (Data Comm) on verbal communication and coordination for multi-sector air traffic management. The results suggest that the use of Data Comm significantly decreases the duration of individual verbal communications.

INTRODUCTION

The Next Generation Air Transportation System (NextGen) concept developed by the Joint Planning and Development Office outlines a transformation of air traffic management from the current system to one in which traffic is managed in a much more strategic fashion. Development of new technologies, such as digital data communication, better aircraft surveillance, and automation-supported conflict detection and resolution, is expected to support the transformation to trajectory-based operations. It also provides an opportunity to explore new team configurations that may better take advantage of the new technologies by reallocating the roles and responsibilities among the various air traffic service providers.

One concept under consideration modifies the standard team configuration within an air traffic facility (e.g. controllers, Area Supervisors, Traffic Management Coordinators, etc.) to include a new position called Multi-Sector Planner (MSP). There have been numerous investigations in the U.S. and Europe (Corker, Liang, Lee, & Prevôt, 2007; Herr, Teichmann, Poppe, & Sharez, 2003) exploring different variants on the MSP position with the common assumption that in the future air traffic environment aircraft trajectories can be strategically managed across multiple sectors.

The current investigation of the MSP position examines the MSP who performs the functions often associated with traffic flow management but works the traffic at a much closer time horizon and by manipulating individual aircraft trajectories. In this concept, the MSP assists with trajectory and flow management functions by assessing traffic complexity and flows across several sectors and within an effective planning timeframe between approximately 30-60 minutes and then rerouting aircraft to manage the complexity and/or redirect the flows around traffic constraints (e.g., weather cells). Working at a time horizon less immediate than that of the sector controller but closer in time than the Traffic Management Unit, the MSP has the potential to reduce delays and provide more efficient routing options when aircraft must be rerouted.

A large-scale human-in-the-loop simulation investigating the operational and technological requirements and feasibility of the MSP concept was carried out in 2009 (Smith et al., 2010). The current paper examines a subset of the data from the larger simulation, namely, the verbal and data communication and coordination between MSPs.

Rationale for the Current Study

One of the key feasibility questions for the MSP concept has been whether the extra coordination layer, created by adding MSP positions to the existing team configuration, would result in an unmanageable amount of required coordination. Given that one of the main MSP functions is to create and send 4-D trajectory reroutes, we hypothesized that the availability of ground-ground data communication (Data Comm) for sending and receiving route trajectories would offload verbal communication and coordination, thus increasing the feasibility of the MSP concept.

There are several features of the prototype Data Comm system that we developed for our study, in particular the ability to create and send graphical 4-D trajectory reroutes on one or more aircraft, which may be suited to facilitating verbal communication. For one, the visual modality is particularly efficient for spatial communication. Verbally describing 4-D trajectories, particularly those based on lat/long coordinates and not restricted to pre-defined VORs, waypoints, or fixes, can be cumbersome at best. Having a common visual reference might also reduce the number of miscommunications and consequent verbal clarifications. Further, our prototype Data Comm tools provided a mechanism to send and receive graphical representations of aircraft and routes between ANSPs, which can facilitate the aircraft identification process by providing immediate visual feedback on the aircraft and routes that have been sent and thereby eliminating the typical pause in verbal communications while one party searches for the target aircraft.

Therefore, we hypothesized that verbal coordination that was accompanied by Data Comm coordinated trajectories would be faster than verbal coordination alone, mainly because the ability to share graphical trajectories would facilitate referencing the aircraft and describing the trajectories between the ANSPs who may not be co-located. In this study, we asked participants to verbally coordinate trajectory/flow plans with everyone impacted by the plan. Given this procedure, Data Comm was not likely to significantly reduce the total number of coordination requests, but we hypothesized that it would reduce the duration of verbal communications. We were also interested in exploring whether the language used to achieve conversational common ground in verbal communications differs when Data Comm supports the communication.

METHOD

The data reported here are taken from a larger study conducted in 2009, a full description of which is beyond the scope of the current report; only the relevant methods are described here. A more comprehensive report on the simulation in its entirety can be found in Smith et al. (2010).

Simulation Facilities

The study took place at the NASA Ames Research Center in the Airspace Operations Laboratory (AOL) using the Multi-Aircraft Control System (MACS) simulation platform (Prevot et al., 2006). MACS has been used to quickly prototype NextGen functions to support numerous concept evaluation simulations. All of the basic controller functions for today’s operations are available in MACS but it also augments the displays to include anticipated NextGen functions such as conflict probe and Data Comm.

In order to support the MSP study, functionalities of the MACS displays were expanded further to include a suite of MSP tools. This prototype MSP workstation included a Traffic Situation

Display with weather forecast information and a high-fidelity Display System Replacement emulation which could be used to filter aircraft, construct routes, and coordinate the routes with others. The MSP workstation also provided tabular and graphical displays of current and predicted sector load and complexity. Most relevant to the current report, the prototyped tools provided graphical and/or keyboard input methods for multi-aircraft selection and trial route planning. These tools allowed MSPs to create provisional 4-D reroute plans for one or more aircraft and to communicate these plans to other MSPs via Data Comm. Additionally, Voice Switching and Communication System (VSCS) emulation allowed for verbal point-to-point and progressive conference calls between positions.

Participants, Training, and Study Design

The MSP participants were two Front Line Managers and two Supervisor Traffic Management Coordinators, each with over 20 years experience in air traffic management. The MSP team participated in 4 days of training on the concept, operational procedures, and use of the tools and VSCS. The data were collected over 2 full days of simulation, each consisting of 4, 75-minute runs. The simulation runs alternated between high traffic loads and convective weather problems.

The simulated airspace consisted of high altitude airspace of Kansas City Center (ZKC) and part of Memphis Center (ZME), and was staffed by four MSPs. The traffic and weather scenarios were designed to put the most pressure on the eastern half of ZKC. Therefore, eastern ZKC was split into a north and south half and assigned to one MSP each while western ZKC and northeastern ZME were each assigned an MSP. MSP participants were instructed to monitor the 30-60 minute time horizon traffic situation and sector complexity within their respective areas of responsibility to ensure that controller workload remained within safe and manageable levels. If they determined reroutes were needed, they were asked to coordinate with each other as necessary, using the tools to plan, coordinate, and execute these reroutes. No specific instructions on what to say during the coordination process were given; participants were free to decide.

RESULTS

Given that conference calls were in general longer and were not often associated with Data Comm, we decided to include only dyadic calls in our analyses. Across the 8, 75-minute runs the MSPs placed a total of 145 dyadic calls to each other.

Measuring Call Length

The VSCS automatically created a separate audio file for each voice call, and audio file length (in seconds) was used for call duration. Recording was voice activated and began when the first person spoke and ended after three seconds of silence. Therefore, ring time was excluded.

Associating Data Comm with Voice Calls

In their calls, participants did not always make explicit reference to the fact that they were discussing a plan sent via Data Comm. Therefore, for each Data Comm sent, voice calls between the initiator and recipient that preceded and followed the Data Comm by up to 10 minutes were checked for references to information contained in the Data Comm. As an example, a Data Comm message sent from the South MSP to the West MSP at 10:56:05 a.m. containing a vertical trajectory modification for aircraft SWA364 was coded as associated with a voice call placed by the South MSP at 10:56:24 a.m. with the content, “Hey West, Southwest three six four just north of Tulsa there, if you could get him down to 28,000 feet [for] complexity in [sectors] twenty-nine and ninety."). The surrounding ten minute interval was chosen because Data Comm messages "timed out" and were deleted from the MSP displays if not acted upon within ten minutes.

Of the 145 MSP voice calls, 101 were associated with a Data Comm message. In 97 of these, at least one of the related Data Comm messages (if there were multiple associated with the call) was sent before the voice call was placed, and on average the voice call followed the Data Comm by about 30 seconds (M = 29.0 s, S.D. = 23.8 s).

Coding Voice Calls

Voice calls were coded into one of two categories, those intended to coordinate a plan of action to solve a particular traffic problem and "other". Only the former were used in the comparison of voice call durations. Sixteen MSP calls were coded as "other." These included calls whose purpose was simply information gathering or sharing (e.g., "Hey West, this is South. I'm going to send you a [Data Comm message] and I'll call you right back." and "…South, who did you take down, reference your busy sector, so I don't duplicate the effort? …Would it have affected m[y area]?..."). These calls were typically not accompanied by a Data Comm message; only two of sixteen were accompanied by Data Comm.

The remaining 129 calls were placed in order to coordinate a plan of action. The majority of these calls were preceded by an associated Data Comm message (95 of 129 calls). In 4 cases, the associated Data Comm message followed the voice call, and these cases were combined with the non-Data Comm supported voice calls for analysis since the Data Comm information was not present at the time of the conversation. In line with our prediction that Data Comm would offload verbal communication, calls that were preceded by Data Comm were shorter than those that were followed by or unassociated with Data Comm (Ns = 95 and 34, Ms = 24.4 s and 32.7 s, S.D.s = 10.1 s and 16.5 s, respectively; $F(1,128) = 11.70$, $p < .01$; Fig. 1).

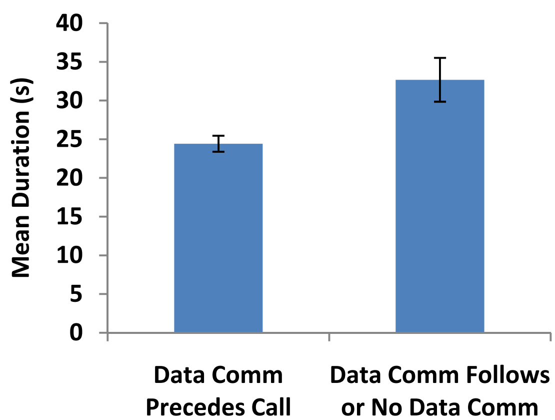

Figure 1. Mean duration of dyadic voice calls. Error bars represent standard error of the mean.

Voice call content was also coded for the presence of specific references to aircraft call signs and identification numbers, as well as more general references to traffic flows (e.g., "JFK landers"). Some calls included both types of references. Voice calls preceded by Data Comm were proportionally more likely to contain a reference to specific aircraft call signs or identification numbers (92% with and 65% without Data Comm; $\chi^2 = 13.80$, degrees of freedom = 1, $p < .001$). Voice calls not preceded by Data Comm were proportionally more likely to contain a reference to a particular traffic flow (24% with and 47% without Data Comm; $\chi^2 = 6.20$, degrees of freedom = 1, $p < .05$). Table 1 presents typical calls with and without Data Comm.

Table 1. Example Voice Calls

Data Comm message preceded call	
Example 1. M: South, this is, uh, Memphis. S: Yeah, November eight zero eight, can you take him west for weather? M: Uh, yes.	**Example 2.** W: West. N: Hey West, this is North. TMU just called me and they wanted Midex seven six two and Mesaba seven two six - you should have them on your scope there - rerouted. [The r]outes [are] in there, if you concur, could you send them to your controller? W: I'll take care of it.
No Data Comm message associated with call	
Example 1. S: South. W: Hey South, this is West. I'm looking at, like, about four Louisville guys heading into the weather there. You want to take care of that amongst your controllers, and you want them to go south or north, or do you want me to take care of it? S: If it's a simple fix, take care of it. That'd be wonderful. W: Well, it's, it's, ok, we'll take care of it. S: Thank you very much.	**Example 2.** N: North. W: Hey North, this is West. I'm looking at a bunch of my guys heading into your weather there. I'm thinking of going up over Quincy with them. Um, in your sector, uh, it's like thirty minutes away, in your sector ninety-two and ninety-four's airspace. N: Yeah, that's fine. W: Um, right, right uh... N: Yeah, they're probably going through there anyway. W: Alright, we'll do that.

DISCUSSION

Most MSP-MSP communication and coordination was carried out with the help of Data Comm. Consistent with their training, downstream MSPs tended to identify a predicted traffic or weather problem in their area of responsibility, develop a set of reroutes to solve the problem, and send those proposed reroutes via Data Comm to the upstream MSP responsible for the area where the subject aircraft were located. The Data Comm message was typically followed by a voice call from the downstream MSP to ascertain whether the upstream MSP was amenable to the request and would forward the request on to the sector controllers.

Notably, the use of Data Comm prior to voice calls as a part of the plan coordination decreased subsequent voice call length. This is probably in part because the Data Comm contained information that would otherwise need to be spoken. For example, instead of verbally describing a desired route modification, plan initiators could simply point recipients to a Data Comm. Once the recipient pulled up and viewed the graphical representation of the reroute, a simple "WilCo" was often all that was required. Data Comm also made it easier for recipients to locate the subject aircraft. Rather than typing in one or more aircraft call signs to bring up their flight data blocks and/or visually searching the display for the subject aircraft, the recipient could simply click on the received Data Comm message notification and thus bring up the 4-D trajectory. This may also be why voice calls preceded by Data Comm more frequently referred to specific call signs. Without an accompanying Data Comm message, subject aircraft may have been easier to locate by relying on the general spatial locations and directions of different flows.

While Data Comm appears to have facilitated communication and coordination, we cannot say whether it could have reduced the number of verbal communications since our protocol required verbal coordination. Consistent with the training we provided, the majority of Data Comm messages were accompanied by a voice call. One reasonable prediction would be that there would be fewer verbal communications when Data Comm was used, since participants could plan, propose, accept, and execute traffic initiatives all via Data Comm.

However, there is reason to suspect that these supplemental voice calls would still have been necessary, even if they had not been formally required in this simulation. One reason may be the inability to embed the reason or intent for a reroute request in the Data Comm itself. Similarly, the receiver of the requests could accept or deny requests via Data Comm, but they could not embed an explanation for their acceptance or denial. A limited intent communication may be possible via Data Comm, such as embedding a brief annotation like “To avoid Wx in ZKC 94” along with the trajectories. Further development is needed to prototype and evaluate such a tool.

Another reason voice calls might have been necessary even with Data Comm, is because verbal conversation may have been more conducive to active negotiation. In its current instantiation, proposed 4-D reroutes sent via Data Comm needed to be accepted “as is” or denied. Participants did not have the option of modifying received reroutes, although they could choose to select and approve only certain reroutes out of a group received together. Therefore, verbal communication was needed so that the plan initiator could learn why his plan was rejected and what alternative reroute options were available to solve his traffic problem. One solution to these required voice calls might be to allow the Data Comm recipient to alter the reroutes in a way that works for his area and to send the modified Data Comm back to the original initiator for final sign-off. Again, it would be helpful if the recipient could know via Data Comm what problem the reroutes were originally meant to solve.

Overall, the results suggest that Data Comm may offload verbal coordination of reroute plans. While voice calls may not have decreased in number, they decreased in length when preceded by Data Comm. Additional enhancements, some relatively minor, to the currently prototyped AOL Data Comm capabilities may further decrease the amount of verbal coordination required. It must be noted though that the current study was merely correlational and not an experiment proper, since access to Data Comm was not manipulated. Further research examining in a controlled manner Data Comm’s impact on verbal communication and coordination is warranted.

REFERENCES

Corker, K., Liang, D., Lee, P., & Prevôt, T. (2007). New Air Traffic Management Concepts Analysis Methodology: Application to a Multi-Sector Planner in US Airspace. *Air Traffic Control Quarterly*, *15*(4), 347-367.

Herr, S., Teichmann, M., Poppe, M., & Suarez, N. (2003). Gate-to-Gate Key Concept Multi Sector Planning (Version 0.5). Langen, Germany: DFS Deutsche Flugsicherung GmbH.

Prevot, T., Lee, P., Martin, L., Mercer, J., Palmer, E., & Smith, N. (2006). Tools for Trajectory-based Air Traffic Control and Multi Sector Planning. *HCI-Aero 2006*, Seattle, WA.

Smith, N., Lee, P., Prevot, T., Lee, H., Kessell, A., & Homola, J. (2010). A Human-in-the-Loop Investigation of Multi-Sector Planning Operations in the NextGen Mid-Term Timeframe. *10th AIAA Aviation Technology, Integration, and Operations Conference*, Fort-Worth, TX.

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