Simulated Task Environment for HCI Analysis of NextGen Data Comm

Maricel Medina-Mora
Lance Sherry
Center for Air Transportation Systems Research
George Mason University,
Virginia, USA
mmedinam@gmu.edu,
lsherry@gmu.edu

Jeroen Hoppenbrouwers
Hoppenbrouwers Engineering
Tilburg, The Netherlands
hoppie@hoppie.nl

Deborah A. Boehm-Davis
Department of Psychology
George Mason University
Virginia, USA
dbdavis@gmu.edu

ABSTRACT

This paper describes a simulated task environment (STE) created to study the impact of using data versus voice communication in the National Airspace System (NAS). Currently, all communications between air traffic controllers and the aircraft they control are by voice. The vision for the Next Generation Air Transportation System (NextGen) is for all communications to be handled through data communications (Data Comm).

The transition to data communications is expected to produce a number of benefits, including a reduction in voice frequency congestion, a reduction in the number of errors made in the transmission process, and a reduction in delays, leading to enhanced sector productivity and capacity. For these benefits to be realized, though, it is critical to analyze and understand the ways in which pilots interact with the system and the ways in which the changes in communication style affect a pilot's awareness of their environment. Thus, additional research is needed and, for that to happen, an environment in which these systems can be evaluated is needed. We developed an STE to meet those needs. The STE integrates five different software tools including a low-fidelity flight simulator into a desktop computer. This is a cost-effective environment that can be used to perform studies to analyze human computer interaction behavior.

Keywords
NextGen, Data Comm, simulated task environment, system analysis and design, usability, party line.

INTRODUCTION

Data Communication (Data Comm) is one of the key technologies needed to implement the Next Generation Air Transportation System (NextGen). In the current National Airspace System (NAS), all communications between air traffic controllers and aircraft are by voice. According to the FAA [3], analog voice communications can contribute to operational errors due to miscommunication or stolen clearances; they also result in delayed messages due to frequency congestion. In 2004 and 2005, approximately 20 percent of en route operational errors were voice communications related. Of those, 30 percent of the high severity operational errors were deemed to be communications-related [3].

Under NextGen, communication will be handled by a two-way data communication between controllers, automation and flight crews. Data Comm is an automated message-transferring system between aircraft and ground stations and is one of the major enablers of NextGen. The implementation of a new communication protocol requires changes at multiple levels, and human-in-the-loop studies are needed to elicit requirements and design the system. These studies may include cognitive walkthroughs, part-task, whole-task and multi-agent simulation experiments. The results of these experiments will be critical to ensuring that the new communication system will optimize pilot and controller performance. Among the expected benefits are a reduction in controller/pilot verbal communications, a reduction of errors on both sides, a reduction in delays, and enhanced sector productivity and capacity.

Although the European Union has already mandated the use of a data communications system and several studies have been performed in this field using high-fidelity simulators [6][10], questions remain for the United States Federal Aviation Administration, who will be writing requirements for U.S. systems in the near future. Many of the questions to be addressed concern human factors issues, such as how best to display information so that pilots maintain the highest levels of situational awareness or how to display responses from the cockpit to air traffic controllers such that they maintain an awareness of the pilots' response to sent clearances. In turn, this research requires the availability of prototyped tools and systems. To support the conduct of this research, a simulated task environment (STE) must be developed. An STE provides a setting that adds controlled complexity to experimental tasks performed by human subjects in a research laboratory [5]. Because it is not always feasible to analyze the problems in a real environment, an STE allows researchers to study a problem more easily. An STE can use high-fidelity simulations; however, the complexity of such simulations can be as difficult as the real world to study. As an alternative, low-fidelity simulations and the integration of other tools can provide an STE that allows researchers to measure the performance of participants with a high level of confidence.

This paper describes the STE that was developed to study the potential loss of situational awareness that could arise from the switch from voice communications to data communications.

RESEARCH REQUIREMENTS

To support this research, a STE was created to include data communication, voice communication, and flight simulation. The simulation needed to address the following requirements:

- Support for two pilots, one serving as the flying pilot and one serving as the non-flying pilot. Two displays of the cockpit are required, one for each pilot.
- Allow the pilots to control the flight path of the aircraft using a flight management system. Given that the initial application of these systems will be in the commercial aviation domain, there was a desire to have the simulation represent a commercial airplane.
- Allow the controller and pilots to communicate with each other either through voice or data communications channels. As part of this requirement, a method that allowed the pilots to see the data clearances and respond to them was necessary.

SIMULATED TASK ENVIRONMENT (STE)

The STE was created using a combination of tools to meet the requirements of the experiment. The experiment used four linked desktop computers. Three of the computers were used by pilots, and one computer was used by the air traffic controller and researcher running the study.

The three computer monitors used by the pilots were arranged horizontally. The left-most monitor displayed the cockpit, and this computer was controlled by the flying pilot. The right-most monitor displayed the cockpit to the non-flying pilot for reference. The center monitor displayed up to three different windows, depending on the experimental condition, of a multipurpose control and display unit (MCDU) that was connected to the cockpit via a broker. One window allowed the non-flying pilot to access the same features as in a standard cockpit flight management system (FMS), such as making changes to the route. The second window displayed Data Comm messages from the controller to the pilot participants. The last window was used to display Data Comm messages between ATC and other simulated aircraft (Figure 1).

Software

On all computers, the following software was installed:

- Roger Wilco [4]: An application that enables communication over the Internet similar to two-way radio.
- Morae [11]: A software application for usability testing that records all interactions (flying pilot, non-flying pilot, and controller) along with a time stamp. This tool allowed capturing the pilots' interactions with the simulation.

On the flying pilot's computer, the following software was installed:

- Aerowinx 747-400 Precision Simulator (PS1) [2]: A simulated Boeing 747-400 aircraft manipulated through joystick and mouse.
- PS1 Broker [7]: Communications software that enables interaction with other add-ons for PS1. This was needed to allow interaction with the remote MCDU (see below) used by the non-flying pilot.
- ACARS Airborne Client [8]: A client program that allows airplanes to communicate to air traffic control through a nearly complete Controller Pilot Data Link Communications (CPDLC) system.

The non-flying pilot controlled two monitors. One had PS1 displayed and the other had the external MCDU [7]. This is a generic, network-enabled virtual console that allows connection to PS1 and control of the FMS.

The air traffic controller's computer had ACARS ATC Client [9] and Adobe Connect [1]. Adobe Connect was needed to display the aircraft's path and/or current status to the controller and researchers was needed. This software is used to create information and general presentations, online training materials, web conferencing, learning modules, and user desktop sharing. This software was used by the air traffic controller to monitor the flying pilot's screen so that the controller would know when to deliver messages.

Finally, a broker was needed to allow the different components of the simulation to interact with one another.

Voice Communication Scenario

The voice communication scenario used the Roger Wilco software to send messages. The flying pilot was in charge of flying the simulator; the non-flying pilot was in charge of controlling the MCDU. A script was created to include other aircraft in the vicinity of the flight. Voices simulating other pilots were recorded and played by the researcher at predetermined times to simulate ATC workload.

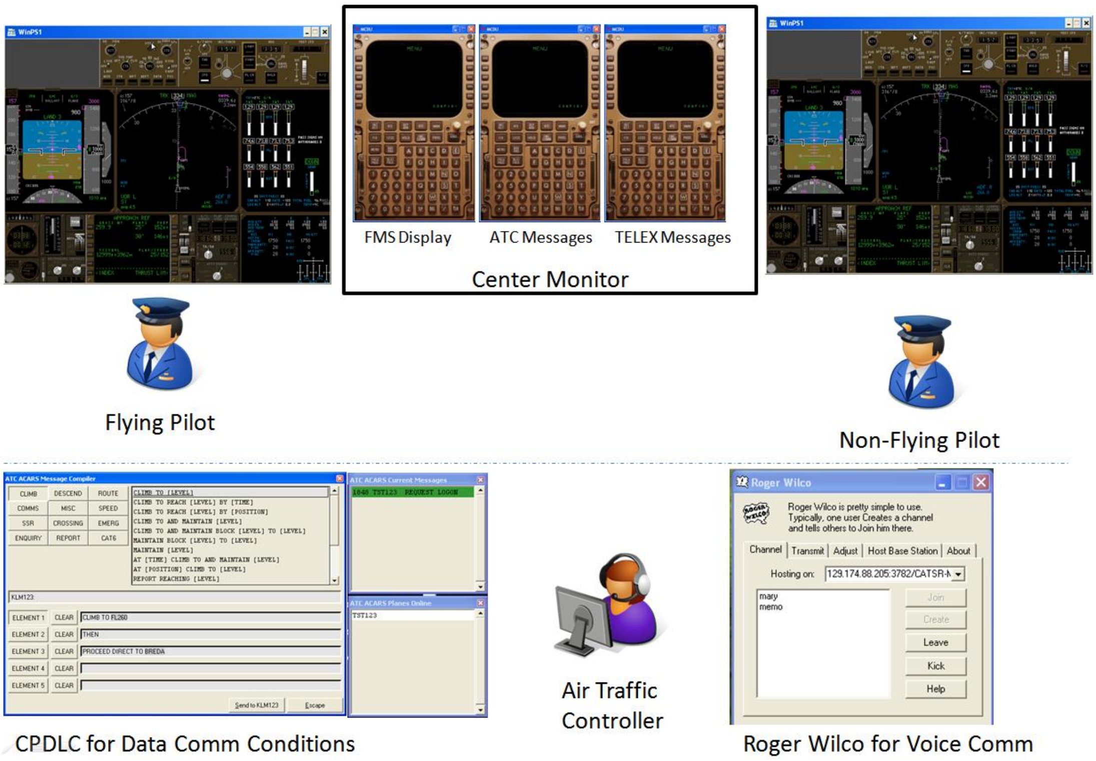

Figure 1 Simulated Task Environment

Pilots and the controller used a headset and pressed a key any time they needed to send a voice message. The interaction that participants had with the voice communication configuration was very similar to what they have under current conditions in a commercial air carrier environment.

Data Communication Scenario

When data communications were used, messages were sent between the pilots and the air traffic controller using the CPDLC system through an Internet connection. Both the non-flying pilot and the air traffic controller connected to the CPDLC system to be able to receive and send messages. When messages were sent from the pilot, the ATC received the request and responded (Figure 2). The air traffic controller sent. Data Comm messages to the aircraft either using predefined messages or using free text messages. The CPDLC system allows creating, editing, and deleting predefined messages.

Every time the ATC sent a message to the pilots, a chime was produced, and the MSG label on the MCDU was illuminated. The non-flying pilot accessed the message and was provided with standard response messages for use in responding to ATC.

Human Computer Interaction Metric Collection

Different human computer interaction (HCI) metrics can be collected from the STE. Performance and time on task can be collected by re-playing the Morae files. Because it took a lot of time to analyze Morae files, a keystroke log fle was developed by Hoppenbrouwers. Time on task for data communication can be collected by analyzing an MCDU.log file generated by the MCDU application. The log file contains the time stamp, the key pressed and the information that was available in the scratchpad. By reading the file, the recreation of the actions can be derived and the actual time that it took the pilot to perform the task can be obtained. To the authors' knowledge, there is no other application that stores this information, reducing tremendously the computation of time on task

Figure 2: CPDLC - Message Received by Pilot from ATC

and recreation of actions performed by a user on a MCDU application.

LESSONS LEARNED FROM APPLICATION OF THE STE

The developed STE was used on two studies that required pilots to conduct flights, or portions of flights, between Dulles International Airport (KIAD, Washington, DC) and John F. Kennedy International Airport (KJFK, New York). In the scenarios, the format in which information was delivered (voice or data communications) was manipulated. In addition, the availability of the party line was manipulated, where party line is defined as the information that pilots discover by listening to communications between other pilots and the air traffic controller while tuned to the same voice frequency.

The conduct of the studies provided us with a number of lessons learned. First, we learned that it is critical to recruit pilots who are already familiar with the Boeing class of aircraft. Pilots unfamiliar with a Boeing cockpit were unable to understand the controls in the simulated B-747 cockpit. Pilots experienced with the Boeing cockpit could learn to use the simulation and the MCDU in roughly fifteen minutes.

Second, we encountered a number of problems while running the studies.

- Connection connectivity lost: The entire environment was connected by a fixed TCP/IP address. When we changed a computer and forgot to re-assign the IP address, the whole system failed.
- Simulator failed: During some runs, the simulator failed and exited without notice. Every time a crash occurred, we reset the computer to minimize the risk of further crashes.
- Unnoticed Data Communication Messages: In the first study, a chime was not provided at the time the MCDU message was displayed. Although the MCDU had a light and the message appeared in the message log, it was not always sufficient to command the attention of the non-flying pilot. Pilots often missed the presence of a new message for quite some time. Prior to the second study, we added a chime that played when the message was displayed. Once the chime was included, the pilots were immediately aware of the existence of a new data message.

Third, we noted that use of the Internet and our broker software would allow us to collect data from pilots who are not co-located with us in our laboratory. This would allow future data collections to draw on pilots located at remote sites, reducing the need for pilots to travel to our location to participate in research.

CONCLUSIONS

The STE developed appears to provide a powerful tool for studying human computer interaction issues that will need to be addressed prior to the development of requirements specifications for U.S. Data Comm systems. The technology enables analysis without requiring complex and expensive simulators. Furthermore, the STE can be easily adapted to perform studies with subjects that are not physically located in same place.

ACKNOWLEDGMENTS

This project was funded by the Federal Aviation Administration (FAA) Air Traffic System Concept Development and Validation Group (AJP-66). The study was overseen by Levent Ileri in the AJP-66 office. The opinions expressed in this manuscript represent a consensus of the authors and do not necessarily represent the official position or policies of the U.S. Federal Aviation Administration. The authors would like to thank Sara Gee, David Cades, Megan Kaminski, and Kelley Baker from the Psychology Department at George Mason University for feedback on earlier drafts of the paper.

REFERENCES

1. Adobe. Adobe Acrobat Connect Pro. http://www.adobe.com/mena/products/acrobatconnectpro/.
2. Aerowinx. 747-400 AeroWinX Precision Simulator PS1. http://aerowinx.com/.
3. Federal Aviation Administration. NextGen Data Communications Program Overview. http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/atc_comms_services/datacomm/general/.
4. GameSpy. Roger Wilco - Communication Technology. http://rogerwilco.gamespy.com/.
5. Gray, W.D. Simulated task environments: The role of high-fidelity simulations, scaled worlds, synthetic environments, and laboratory tasks in basic and applied cognitive research. *Cognitive Science Quarterly 2*, 2 (2002), 205–227.
6. Hoogeboom, P., Joose, M., Hodgetts, H., Straussberger, S., and Schaefer, D. Does the 'silent cockpit' reduce pilot workload? *Digital Avionics Systems Conference*, (2004), 1:5.D.5- 5.1-9.
7. Hoppenbrouwers Engineering. PS1 Broker. http://www.hoppie.nl/broker/.
8. Hoppenbrouwers Engineering. ACARS Airborne Client. http://www.hoppie.nl/acars/prg/air/.
9. Hoppenbrouwers Engineering. ACARS. http://www.hoppie.nl/acars/.
10. Pritchett, A. and Hansman, R. Variations in 'Party Line' Information Importance Between Pilots of Different Characteristics". *Eighth International Svmposium on Aviation Psvchology*, (1995).
11. TechSmith. Morae - User Testing and Market Research Software. http://www.techsmith.com/morae.asp.