Safer Skies

Usability at the Federal Aviation Administration

BY FERNE FRIEDMAN-BERG, PH.D., KENNETH ALLENDOERFER, CAROLINA ZINGALE, PH.D., AND TODD TRUITT, PH.D.

AIR TRAFFIC CONTROL (ATC) PROVIDES A CLASSIC EXAMPLE of expert users interacting with technology in a complex, high-stakes environment. With thousands of flights every day in the U.S., one controller can be responsible for more than a dozen planes at once. Controllers make decisions and communicate by relying on their experience and skill, in addition to using complex and sometimes arcane technology. Controllers often talk about how proud they are to be "tin pushers," how interesting and challenging their work is, and how much they enjoy it. As usability professionals working in ATC, we feel much the same way.

The Atlantic City Federal Aviation Administration (FAA) Human Factors team conducts human factors research and develops ATC systems from a human-centered perspective. We study user communities that include air traffic controllers and technical operations specialists who maintain the intricate radar, navigation, communication, and information technology that make up the ATC system.

We work at the FAA Research Development and Human Factors Laboratory (RDHFL), part of the William J. Hughes Technical Center in southern New Jersey. We publish the *FAA Human Factors Design Standard*, a comprehensive, free reference for designing effective systems, equipment, and environments (available at http://hf.tc.faa.gov/hfds).

At our lab, we have all learned to become human factors jacks-of-all-trades. We use a variety of methods ranging from field observations and interviews, to rapid prototyping and "discount" usability assessments, to full-scale, highly realistic simulations complete with eye tracking and metrics of cognitive activity. One week, we might travel to ATC facilities to survey controllers in the field about a newly deployed system. The next, we might conduct a cognitive walkthrough on candidate systems the FAA is evaluating for use in the near-term ATC environment. After that, we might run a human-in-the-loop simulation to measure how to implement future concepts in the national airspace system.

Our researchers have various backgrounds. Some have a Ph.D. in cognitive psychology, human factors, or information science. Others come to the lab with bachelors or masters degrees and have proceeded to complete graduate work while supporting the lab. Many of us did not plan to perform aviation research while in graduate school, but because of the interesting nature of the work, the variety and breadth of the research we conduct, and the impact our work has on the aviation system at large, we cannot imagine a more challenging and exciting career.

The Big Airspace Project

With the demand for air travel projected to increase in already crowded areas over the next twenty years, the FAA is concerned about how the airspace system should evolve to handle such a large increase. We recently investigated a concept, "Big Airspace," that could potentially increase capacity and alleviate congested airspace around major metropolitan areas. It would allow aircraft to fly closer together and make airspace boundaries more flexible.

In today's system, two aircraft flying at cruising altitude, which is known as en route airspace, can be no closer than five nautical miles. Big Airspace allows controllers to reduce the minimum distance between aircraft to three nautical miles, which is the standard currently used in terminal airspace closer to the airports. The reduced separation provides room for more routes and allows controllers to sequence and space aircraft further from the airport.

The Big Airspace concept also allows airspace boundaries to be readjusted more readily in response to disruptive situations such as bad weather. Finally, to enhance communication and coordination, this concept allows controllers working Big Airspace sectors to be located in the same facility. En route and terminal controllers for a particular airspace do not currently work in the same building and are often not even located at the airport.

In this study, one condition simulated today's airspace and procedures and the other two simulated Big Airspace. One of the Big Airspace conditions allowed en route and terminal controllers to work as they do today—in separate facilities communicating over the phone. The other simulated a future control room environment where they were located in the same room and were able to communicate with each other directly.

We compared system and controller performance, efficiency, and safety across conditions. The results provided support for the Big Airspace concept: aircraft moved through the arrival airspace more efficiently; spent less time, and flew a shorter average distance. The Big Airspace controllers also reported lower workload, made fewer phone calls, issued fewer altitude and heading instructions, and needed less assistance from other controllers to hold and manage traffic before it entered their airspace. Controllers were also able to maintain or even reduce their workload in bad weather. With these positive results in hand, the FAA can begin the process of implementing the Big Airspace concept in the actual ATC system.

Optimizing Safety Alerts

When things start to go wrong in ATC, technology provides controllers with alerts intended to draw controllers' attention to possible conflicts between two aircraft, known as conflict alerts (CAs), or between an aircraft and a physical obstruction on the ground, known as Minimum Safe Altitude Warnings (MSAWs). CAs and MSAWs are designed to activate while there is still enough time for controllers to address the situation before issues become too serious to correct.

The alerts appear on controllers' radar displays and there may be an accompanying audible alert. We wondered if the design of the alert unintentionally makes it harder for controllers to respond appropriately.

In 2006, the FAA asked us to examine this issue in response to a series of accidents and incidents where controllers seemed to have not seen visual or heard audible alerts. In these cases, controllers failed to respond appropriately or in enough time to fix the problem. The National Transportation Safety Board (NTSB), in response to similar incidents, recommended that the FAA redesign these alerts to "reliably capture and direct controller attention to potentially hazardous situations."

We conducted a thorough analysis of today's alerting systems. We visited several ATC facilities to observe controllers, examined ATC automated data recordings, and transcribed many, many hours of live voice recordings of alert situations. We categorized how controllers responded, and analyzed when responses occurred relative to the activation of an alert. This analysis allowed us to develop recommendations for improving the human-factors attributes of the current alerting systems.

We found that a large percentage of alerts received no response from controllers. Also, none of these non-responses led to operational errors or deviations, which are violations of safety rules. When controllers responded to potentially unsafe situations, most responses occurred prior to the alert activation. For example, many alerts lasted for such a short duration that the only reasonable conclusions were that controllers must have addressed the situations prior to the alert or that the situations resolved themselves without any action. Our analysis indicated that many as 81 percent to 97 percent of CAs and MSAWs were nuisance alerts.

A large number of nuisance alerts can create serious problems. By design, alerts cause controllers to interrupt current tasks and focus on the aircraft involved in the alert situation. Frequent and unnecessary interruptions increase the workload and reduce overall performance. A large number of nuisance alerts can lead to controller desensitization, which in turn leads to poor response to genuine alerts and reduced trust in the alerting system.

We concluded that even though controllers were responding appropriately to the alerts, the excessive nuisance alerts negatively affected controller responsiveness to them. On the basis of our analysis of the recordings, we recommended that the FAA make reducing nuisance alerts a top priority and suggested several methods for doing so.

Tracking Heavy Weather and Traffic

Bad weather can close or slow down airports, reduce airspace capacity, and generally make controllers' jobs more difficult and stressful. Controllers are not meteorologists, but they need to use and understand weather-related information to maintain safety and efficiency.

FAA traffic managers try to minimize delays and congestion in the air-traffic system that result from system stressors such as heavy volume, weather, and equipment outages. These individuals must maintain awareness of how inclement weather in one part of the country affects air travel in another. Their focus is on making the entire ATC system run well, rather than just one sector or airport. For example, if there are thunderstorms near Chicago, traffic managers must reroute all traffic that will come close to Chicago, including flights whose final destinations are New York or San Francisco. Because traffic managers use large amounts of data, it is imperative that the FAA employs good user-centered practices developing the systems they use daily.

One system used daily by traffic managers is the National Traffic Management Log (NTML). The FAA developed the NTML to provide a single system for keeping track of traffic-management initiatives. It functions somewhat like an internal bulletin board system.

Until recently, the methods for coordinating, logging, and communicating traffic management initiatives were highly inefficient. Some facilities relied on paper and pencil and others developed their own computerized tools. Coordination was inefficient at best, and was typically accomplished through face-to-face communications within the facility and through phone calls between facilities.

We analyzed the potential savings provided by the NTML in terms of traffic managers' workload. This study asked traffic managers to coordinate, log, and communicate traffic-management initiatives using the NTML and using the methods employed prior to the deployment of the NTML. We found that the NTML provided savings in the time it took to implement initiatives, reduced the potential for user error, and decreased workload. Using the NTML, even when the complexity of the traffic situation increased to where we might expect a large increase in user errors and time to complete initiatives, both increased only slightly.

We also recently developed weather display concepts for convective activity (thunderstorms), visibility, and icing information to meet the needs of en route controllers. The displays will enable the controller to communicate information about weather hazards to pilots. This proposed weather system will also track general aviation aircraft and hazardous weather areas. If the automated system detects a future conflict between an aircraft and hazardous weather, it will notify the controller who can then inform the pilot.

On the Ground

Controllers working in airport traffic control towers direct aircraft as they taxi, take off, and land. They ensure that vehicles such as maintenance vehicles and lawnmowers do not

impede the aircraft. Tower controllers use the same types of communication and information technology as en route and terminal controllers, but they can also look out of the tower windows and observe aircraft directly.

We are currently designing and testing new interface concepts for tower controllers. Currently, tower controllers receive and record information about each aircraft on small pieces of paper, known as flight progress strips. The paper strips contain critical data about each flight, such as its call sign (identifying code), type of aircraft, and intended route. While many companies have developed electronic versions of flight progress strips, the paper strips used in FAA towers have persisted.

Past efforts to create electronic flight progress strips have attempted to preserve their paper-like qualities and appearance. Our researchers followed a different approach. We developed two prototype user interfaces for presenting and interacting with the flight data and other information sources. The Integrated Tower Operations Digital Data System (TODDS) combines electronic flight data with a surface surveillance system (such as radar), weather information, digital communications, and safety automation. The Perceptual-Spatial TODDS uses the same design principles as the Integrated TODDS but does not rely on surface surveillance and is intended for airports where such surface surveillance is unavailable. In addition, the Perceptual-Spatial TODDS may serve as a backup to the Integrated TODDS in case surface surveillance becomes inoperable.

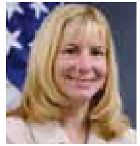
From a usability perspective, the Perceptual-Spatial TODDS allows controllers to spatially organize the data in the manner that they think about it—according to the positions of the aircraft on the airport surface. For example, if three aircraft are scheduled to use the same runway, the flight data for those aircraft are located near that runway on the screen.

These prototypes provide a new method for tower controllers to manage flight data and share information with other facilities while improving efficiency and safety. An initial usability test of the two systems demonstrated that controllers were able to learn how to operate both quickly.

Overall, controllers responded favorably to the new concepts. They thought the interfaces were well organized and easy to use, required little effort, provided all of the necessary flight data, and supported their awareness of the airport traffic situation. However, because there were several functions that were difficult to use, controllers had some concerns that the tools might cause too much "heads down time" which corresponds to the time spent looking at the screen and not out the window. On the basis of that feedback, our researchers improved the usability of the prototype interfaces, and the newest TODDS prototypes address issues identified in the usability test, add new features, and integrate even more information into a single, touch-screen interface. The FAA currently has two patent applications pending for the TODDS prototypes.

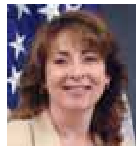
This is only a small sample of the transportation research that the Atlantic City Human Factors team performs. Other recent projects have examined standardizing colors for ATC displays, developing strategies for creating memorable but secure passwords, field studies of new information display systems, and simulations of concepts for the Next Generation Air Transportation System that will be implemented in the 2020s. As the evolving air traffic system faces future human factors challenges, we will proudly continue to do our part to support this work. UX

ABOUT THE AUTHORS



Dr. Ferne Friedman-Berg *is a Federal Aviation Administration engineering research psychologist. She has conducted air traffic control research for over six years.*

Kenneth Allendoerfer *is an engineering research psychologist with the Federal Aviation Administration, where he has spent more than ten years evaluating air traffic control systems.*



Dr. Carolina Zingale *has been an engineering research psychologist with the FAA Human Factors Atlantic City team since 2005, and previously supported the group as a contractor for over three years.*

Dr. Todd R. Truitt *is a private pilot with over thirty publications addressing cognitive factors in air traffic control.*

Additional information about our lab and PDF copies of all of our published technical reports can be found at http://hf.tc.faa.gov.