Training Air Traffic Controllers for Future Next Generation Air Transportation System (NextGen) Technologies

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Acronyms and Definitions

AC…………………Aircraft
ADRS………………Aeronautical Datalink and Radar Simulator
ANIC………………Awareness of the Need for Immediate Communication
ATC………………Air Traffic Control
ATCo……………..Air Traffic Controller
ATM………………Air Traffic Management
CHAAT…………..Center for Human Factors in Advanced Aeronautics Technologies
CSULB…………..California State University Long Beach
Data Comm……..Data Communication
LOS…………….Loss of Separation
MACS…………….Multi Aircraft Control System
NAS……………National Airspace System
NextGen…………Next Generation Air Transportation System
SA………………Situation Awareness
SPAM……………Situation Present Awareness Method
Executive Summary

A group of Human Factors specialists of California State University Long Beach (CSULB) were asked to investigate the most effective training procedure for future air traffic controllers (ATCos), provided the gradual implementation of the NextGen tools in aircraft. The information included in the current report comes from three articles, discussing the results of different techniques of training with NextGen procedures. From this research, the following recommendations were made with respect to NextGen training.

- **Training Procedure:** To ensure future ATCos have an established foundation in NextGen and manual tools, a part-task training technique is recommended.

- **Training Order:** To account for individual differences in communication style, ATCos should be trained on manual tools first, followed by NextGen.

- **Training Trust in Automation:** Trust in automation should be trained to future ATCos to ensure both consistent use of the automated NextGen tools and efficient airspace management.

- **Performance Metric:** The Situation Present Awareness Method (SPAM) shall be implemented during and after training to measure situation awareness (SA) and workload in ATCos. This is to establish an adequate level of performance has been met upon training completion.
1. Introduction

1.1 Objectives

To create the most efficient training procedure for ATCos when managing a mixed-equipage airspace, the objectives of our project were as follows:

- Establish an appropriate measure to ensure student ATCos are trained to an adequate level
- Create the best training method, that incorporates both manual and NextGen tools, while considering individual differences
- Understand the effects of trust in automation on airspace management performance

1.2 Background

Currently air traffic in the National Airspace System (NAS) is managed through a set of manual procedures, including voice communication between the air traffic controller (ATCo) and the pilot, and manual conflict resolution done by visually scanning a monitor with multiple aircraft (AC). With the estimated increase in air traffic within the next 15 - 20 years, ATCos will have more traffic to manually manage and more pilots to communicate with, ultimately creating a high workload for ATCos. The current air traffic management procedures will not be sufficient for ATCos to continue to perform at safe and efficient levels with such a large increase in air traffic. Thus, the Next Generation Air Transportation System (NextGen) has been proposed to solve this problem and decrease the workload in ATCos. NextGen is a complex, semi-automated system intended to create more efficient air traffic management (ATM) by shifting some manual procedures to automated controls. These NextGen tools are further described in Table 1.

<table>
<thead>
<tr>
<th>Conflict Detection</th>
<th>Conflict Resolution</th>
<th>Data Communication</th>
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<tr>
<td>Highlights AC with impending conflicts</td>
<td>Trial Planning tool: plans new route changes Conflict Probe tool: conflict detection of new route</td>
<td>Digital transmission of frequency changes, handoffs, and aircraft clearances.</td>
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However due to cost constraints, NextGen will be implemented in ACs gradually, thus leading to a mixed-equipage airspace, in which some AC will have NextGen tools and some AC will have manual tools.

1.2 Approach

In response to President Strybel’s request, we have reviewed three papers regarding training ATCos in mixed equipage airspace, provided the gradual implementation of NextGen. This request was completed in two weeks through Human Factors specialists of California State University Long Beach (CSULB). The examination of three articles were to answer if:

- Part-task training technique, in which manual tools are taught first, is the most effective method of training
- Training trust in automation will result in optimal use of NextGen tools
- Metrics can be effectively implemented to insure adequate performance upon training completion

2. Method

In the papers reviewed, a majority of participants \( n = 26 \) were student air traffic controllers from Mount San Antonio College, a FAA Collegiate Teaching Initiative (CTI) school. Seven participants were retired air traffic controllers \( M = 25.8 \) years of experience. The research teams conducted the simulations using Multi Aircraft Control System (MACS) and Aeronautical Datalink and Radar Simulator (ADRS) to simulate the Indianapolis Air Route Traffic Control Center (ZID 91 sector). During simulations, air traffic controllers communicated with pseudopilots using a VoiceIP software, DagVoice. All software was provided by NASA Ames Research Center. Mixed equipage (NextGen tools or manual tools) scenarios were included to represent the future NAS environment. Student air traffic controllers were enrolled in a 16-week radar simulation internship at the Center for Human Factors in Advanced Aeronautics Technologies (CHAAT) at CSULB.

3. Results and Recommendations for NextGen Training

3.1 Training Order

*A part-task training technique, in which a whole task is subdivided into subtasks, is recommended.* During the transition of implementing NextGen, some aircraft will include NextGen tools and some will not. Air traffic controllers must be prepared with the mixed-equipage airspace. A solid knowledge of both verbal and automatic commands must be established. Current ATCos will already have an existing schema, or mental model, of the airspace, which will aid them in the acquisition of the new NextGen tools. However future
ATCos, who must learn both manual and automatic commands to account for the mixed-equipage airspace, will not have an existing mental model to aid them and so must be trained with both. These subtasks should be learned sequentially to provide a solid foundation of each skills before moving to the next subtask.

The order in which AC tools are learned will affect performance, especially when individual differences are considered. One such individual difference in communication style is particularly important, as communication failures have been linked to air traffic collisions. Such a communication style, referred to as the awareness of the need for immediate communication (ANIC), relates to the individual’s immediacy for solving communication errors. An individual with high-ANIC will correct errors in the pilot or themselves more frequently than an individual with low-ANIC and thus take greater steps to avoid miscommunication. Research has found that the order in which students receive training (either manual or automation first) will have different outcomes in performance depending on the different levels of ANIC, such that:

- Those with low-ANIC show lower situation awareness and higher workload when trained with NextGen tools first, particularly as the percentage of equipped planes increased.
- Those with high-ANIC were overall unaffected by the order in which they received training

The interaction between individual differences and training order can impact performance. Provided the importance of communication regarding safe air traffic management, those with low-ANIC must be accommodated. Furthermore to create a cost-effective training, one training procedure should be implemented. Thus, the most efficient order of part-task training shall be manual commands first, followed by NextGen tools.

3.2 Training Trust in Automation

We recommend that Next-Gen training include training trust in automation. Human-machine trust is the operator’s expectations that the machine will perform reliably and consistently to achieve the original goal of the system. Trust in automation is an important lesson that novice and experienced ATCos need to learn, as it has been shown to have a significant value in enhancing sector efficiency and reducing ATCo workload. Higham et al. (2013) looked at the number of times in which student ATCos moved near-miss ACs, provided the use of Conflict Detection in each scenario. Near-miss ACs presented a possible collision but would not collide, and thus the Conflict Detection would not highlight the ACs. Thus, moving the near-miss ACs would be inefficient. Students who were trained to trust automation were less likely to redirect the flight path of near-miss AC in an equally mixed-equipped airspace than students who were not trained to trust automation. Therefore, ATCos trained to trust automation tools had more efficient airspace and reported less workload than ATCos not trained with trust feedback. Benefits of trust training include:

- Cost-effective flight operations
- Reduction in scanning of the radar screen for conflicts that do not exist
- Utilization of automated NextGen tools
A tradeoff was seen in scenarios with 100% equipped airspace. While students with trust-training showed a decrease in workload, they also showed a decrease in SA. This reduction may be due to a decrease of actively scanning the radar screen. Rather than searching for potential problems, students seemed to trust that the NextGen tools would alert them with any conflict. While this tradeoff must be further investigated, 100% equipped airspace will not be immediate, and the benefit of trust-training in mixed-equipage airspace is essential in decreasing the workload of ATCos as traffic density increases.

3.3 Metrics

3.3.1 Situation Awareness and Workload

Kiken et al. (2012) provide evidence for one technique to measure situation awareness (see Appendix A for definition). The Situation Present Awareness Method (SPAM) introduces online questions, also referred to as probes, within the current environment in the midst of managing air traffic (see Figure 1). The display is present as the probe is administered, allowing ATCos to use the information from the display to answer accurately. A longer response time indicates a need to check the display. Longer response latencies are associated with poorer SA.

SPAM is also used to measure workload (see Appendix A for definition). Before the probe appears, the ATCo hears a tone, which signals to the ATCo to look at the display. The display then shows a question, asking if the ATCo is ready to accept the probe. Once the ATCo accepts this ready prompt, the probe appears. The amount of time to accept the probe is then calculated. This time, referred to as ready latency, determines the level of workload that an ATC is under. A higher ready latency denotes a higher workload. SPAM also allows for a subjective report of workload through questions, presented throughout the scenario, asking for a rating of workload.

SPAM has been shown to measure the SA and workload of ATCos without affecting the safety of AC and the efficiency of air traffic management within the sector. Thus SPAM will be an effective measure to ensure ATCo students are performing at an adequate level of performance before transitioning to work with real AC.
3.3.2 Safety and Efficiency

Participants were also assessed on their performance during simulations based on safety and efficiency. Safety was measured through the total number of events, in which two AC had a loss of separation (LOS). LOS refers to a violation of the separation minimum of 5nm laterally and 1,000 feet vertically. Efficiency was measured through both the average distance and the average time of AC through the sector, as well as any unnecessary movement of near-miss aircraft.

4. Conclusion

NextGen will be implemented gradually, thus resulting in a mixed-equipage airspace in which some AC will have NextGen tools and some will not. Future ATCos must be trained with both sets of tools to account for the mixed-equipage airspace.

We recommend that training be implemented through a part-task training procedure, in which ATCos are first trained with manual tools and then trained with NextGen tools. The NextGen training will be further subdivided by tools, so that ATCos will learn one tool at a time. The training regarding NextGen will also incorporate trust feedback.

- Through SPAM, which has been proven to measure SA and workload without impacting sector safety, we can ensure the student ATCos will perform at an adequate level prior to training completion.

- The recommended training order accounts for individual differences, thus providing a cost-efficient option that benefits a majority of student ATCos.

Figure 1. Real-time SA and workload probe technique model (ATCo query).
• The trust in automation teaches ATCos to use NextGen tools consistently to increase the efficiency in air traffic management.
5. References


6. Appendix
Appendix A: Definitions

Situation Awareness (SA) is the understanding required to operate a complex system in a dynamically changing environment (Durso and Gronlund, 1999). SA is an important component of ATC performance. The performance of an ATCo is determined by the efficiency of moving AC through the sector safely. In order to perform well, ATCos are continuously updating their mental picture by assimilating information of the ACs’ parameters within their sectors. In the air traffic management system, a rapidly changing airspace with a vast flow of information, poor SA can lead to devastating outcomes. The need to evaluate air traffic controller performance with NextGen tools is critical.

Workload has been defined as the amount of mental effort required to complete a task in a given amount of time. With the increase in air traffic expected, the need to reduce ATCo workload is critical. High workload is detrimental to the effectiveness and safety of the NAS resulting in the need for NextGen technologies to reduce workload. NextGen technologies are expected to alleviate ATCos workload by eliminating excessive communication through the implementation of automated tools. Such tools include automated conflict detection, conflict resolution, and data communication.