Practitioner's Commentary: The Outstanding Air Traffic Control Papers

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Introduction

The problem of introducing computer-assisted aids to the air traffic controller community to improve safety and reduce workload is both relevant and immediate. The Federal Aviation Agency (FAA) in the United States, the National Air Transport Services (NATS) agency in the United Kingdom, and numerous other civil aviation authorities around the world currently are engaged in evaluating, developing, testing, and deploying automated support tools even as these MCM papers were being written. All of the papers correctly identified the two factors that determine automation viability: passenger safety and controller workload.

The air traffic controller community is slow to adapt to and embrace new technology. This is not due to some inherent technophobia by this population but rather is driven by professional concern for air traffic safety. Every controller must maintain regular job certification. A serious incident (e.g., a "near miss") that is traced to an error in their performance can cause them to be pulled from their station and recertified. Air traffic control (ATC) is a three-shift-a-day / seven-days-a-week operation. The entire focus of a controller is on the air traffic moving through the airspace as imaged on her display, and the voices of the pilots in her headset. There is little time to have her attention pulled away from those concerns to learn a new, more complicated series of mouse clicks, or to adapt to a new graphic data format or automation aid. The distraction caused is analogous to that of talking on a cellular phone while driving at high speed on the Interstate—attention is diverted from an exclusive focus on safety. And

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this is already one of the most stressful professions on earth. The introduction of automation to support and expand the controller's focus must be done with great care.

Criteria: Light from the Real World

Each of the four selected MCM papers addressed the problem assigned in a different way. As a practitioner, I chose not to evaluate each on the elegance of the mathematical modeling employed; the MCM judges can concentrate on that. Rather, I examined each from its relevance to the problems facing real air traffic controllers. This is not to criticize any of the teams for not having the insight and experience of practitioners; of course, that is not realistic. Instead, my intent is to shed some light from the real world on each approach that might be useful to both the team members and to other readers. I assessed each paper on three qualities:

- Thoughtfulness: How well did they think through the problem statement before addressing it?
- Realism: How close does the proposed solution come to addressing a real-world problem?
- Usefulness: Is the proposed solution itself applicable to address the world of the air traffic controller?

On this basis, there was substantial variation in the approaches taken by the four teams.

The Best of the Four: University of Colorado Entry

The entry from the University of Colorado team evaluated best by these measures. It was clear that this team spent appreciable time understanding the FAA. The selection of the Denver International Airport as the system model and obtaining the relevant airport, airspace, and ATC parameters from this airport were done extremely well. The team accurately represented the details of the air traffic and correctly asserted that conclusions drawn should translate into other regions. Second, the team used the Federal Aviation Regulations (FARs) as the guidance for resolving technical assumptions. Once again, this shows a real understanding of FAA procedures. FARs are indeed the governing standard for assessing safety.

The use of a "corrected random walk" to validate the FAA's minimum aircraft separation standard was clever. It ignores standard approaches like the computation of minimum maneuver time required for two aircraft approaching head on. However, the model used by this team provides an insight for parallel flight that is novel and confirms the FAA separation standard as well.

The approach taken to quantify stress as a parameter was good. Once again, they researched the available literature to develop a baseline for ATC stress and built the model from there. The model used is both simple and probably applicable. Though arbitrary, the measure of complexity should demonstrate a logical relationship between traffic patterns and workload stress that can provide insight into underlying causes. Of course, the motivation was to allow the team to transform the automation problem into a problem of queueing, thus greatly simplifying the model and still providing insights. The simple queueing model that the team proposed overlooked a significant factor in runway access, which is gate availability (i.e., even though all runways are clear, traffic may still have to hold because there are no available passenger gates). However, their model can easily accommodate this factor.

The results of this model are intuitive and appear to be correct. Further, for the problem of airport terminal approach and landing at least, they correctly identify which elements of ATC need remain under the control of humans and which have potential for automation.

The Other Outstanding Papers

Each of the other three papers, while providing useful insights, misses this mark by several degrees.

The Duke University Entry

The team from Duke University scored well on my (admittedly subjective) scale of "thoughtfulness." They paid attention to the problem description and showed understanding in the model setup and the trades they performed. However, the paper seems to rely heavily on an assumption that pilots control the aircraft and controllers principally intervene to avoid collisions. This ignores the active control of all aircraft at all times by the controller team as each craft navigates through the airspace.

Commercial airline pilots (as contrasted with general aviation or "private" pilots) do not dynamically choose their routes, their airspeed, or their altitudes. All this is under the direct control of the air traffic controller. Each aircraft files a flight plan, which must be coordinated and cleared with the FAA prior to take off. This flight plan sets the cross-country route that that aircraft will follow, and must explicitly follow regulated "highways" leading from one ATC center to another to ensure continuous ATC coverage. The aircraft's flight is under 100% control of the air traffic controllers from the moment of gate departure through gate arrival.

While the Duke University team's approach was thorough in defining the various "automation" programs that might be employed for collision detection and avoidance, it did not address or encompass the information available to every controller about the planned trajectory of the aircraft obtained from its flight plan. Collision detection schemes currently in use, and more advanced techniques now being evaluated by the FAA, combine information from the radar "track" history for the aircraft with the projected trajectory derived from the flight plan. In addition, the team did not adequately explore the cascade effects of ATC actions. In other words, once a controller decides to have an aircraft change altitude, speed, or direction to avoid a potential conflict, that action must be evaluated to see if new conflicts with other craft have been created. Collision avoidance schemes must have a "what-if?" capability embedded to allow controllers to evaluate a number of potential maneuvers for conflict avoidance before making giving final direction to the pilot. Such techniques are currently under evaluation by NATS in the United Kingdom for implementation in their newest En Route Control Center. On balance, however, I thought this paper had a good approach to realism and usefulness.

The U.S. Military Academy Entry

The approach of the team from the U.S. Military Academy addressed the availability of flight data but appeared to overlook radar. While the mathematical modeling employed seemed sophisticated, the effort was directed toward determining the likely deviation of an aircraft from its flight plan by statistical methods alone. This is both complex and unnecessary, since every aircraft under ATC control can be uniquely tracked by radar. Not only does a controller have a positive radar image (or "track") on his screen, but that track is identified graphically with the aircraft identifier available from the aircraft's transponder. Coupled with the flight plan data available for the aircraft, the ATC has explicit knowledge of position, history, and intent. The statistical model employed by this team is largely irrelevant in that case.

Also, the team makes an assumption that curvature of the earth need not be accounted for, which is not true for high-speed aircraft unless projecting conflicts over short time periods. A conflict model currently being evaluated by the FAA explicitly includes earth curvature for that reason. A similar set of comments applies to the team's complexity model; it is an interesting mathematical exercise but not useful. A controller simply viewing his radar display can readily determine complexity of the airspace. An approach to quantify this complexity for evaluation of automation should be direct, as the simplified approach by the University of Colorado team demonstrates by example.

Virginia Governor's School Entry

Finally, the team from the Virginia Governor's School takes an approach that I believe is the least "real world":

- The approach to validating minimum safe separation was unduly complex.

The team's intent was to attempt to model the aerodynamics of a commercial airliner and, from that, to determine how close another craft could approach before being adversely affected by the air flow. This work has already been done by aircraft manufacturers themselves (and by countless generations of Aeronautical Engineering students, myself among them) and could be readily accessed rather than derived from first principals.

- Once the team set out on this endeavor, they were then forced to make a number of oversimplifying assumptions (e.g., modeling the aircraft as a cylindrical ring, defining the fluid dynamics using vortices and Bernoulli's equation). These assumptions are quite wrong for the model and therefore cause the derived conclusions to be suspect.
- Similar sets of simplifying and unrealistic assumptions were used to model potential conflict. For example, the model takes no consideration of the actual sectors of air space and the active control from ATC under which every aircraft operates.

I believe this team's paper would need substantial rework before it could be credibly presented to the FAA Administrator.

Summary

Each team took a very different approach from the others in addressing the stated problem, with significant variation in practicality from the viewpoint of a practitioner. Of the four papers, that from the University of Colorado would be the one I would recommend taking forward as is to Ms. Garvey and her staff for review and further evaluation.

Reference

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About the Author

Jack Clemons is the Senior Vice President of Strategic Programs at Lockheed Martin's Air Traffic Company, located in Rockville, Maryland. Jack joined the Lockheed Martin Corporation in April 1996.

Jack began his career at General Electric Corporation's Reentry Systems Division in Valley Forge, Pennsylvania, now part of Lockheed Martin Management and Data Systems. He then worked on the NASA Apollo and Skylab programs for TRW Systems Group in Houston, Texas, and on the NASA Space Shuttle program for IBM Federal Systems Group, also located in Houston. Following that, Jack spent eight years in new product market development and market support for the IBM Corporation in White Plains, New York, and he served a one-year chair assignment as instructor at IBM Corporation's New Management School in Armonk, New York.

Jack joined IBM Federal Systems Group's Air Traffic Control Company in 1992 as Functional Manager of Software Development. Following the acquisition of Federal Systems by Loral, Jack performed the roles of Director of EnRoute Programs and Vice President of Air Traffic Control Engineering. Following the acquisition of Loral by Lockheed Martin, Jack became Senior Vice President of Engineering, Technology and Operations before moving into his current position.

Jack graduated from the University of Florida with Bachelor of Science and Master of Science degrees in Aerospace Engineering.