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Towards Information Requirements for Airport Traffic Control Towers

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TOWARDS INFORMATION REQUIREMENTS FOR AIRPORT TRAFFIC CONTROL TOWERS

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Biographies and Position Statements of Participants

Dr. Jerry M. Crutchfield

DR. JERRY M. CRUTCHFIELD earned his Ph. D. in Experimental Psychology from the University of Oklahoma in 2005. He has performed air traffic control related research for over 10 years, including 3 years with Boeing Air Traffic Management. He now holds a Principal Investigator position at the FAA's Civil Aerospace Medical Institute.

Jerry Crutchfield's Position Statement

Proposed enhancements to air traffic control (ATC) procedures and technologies are under development to increase the air traffic capacity above that of today's system. Many of these potential enhancements implicate major changes to the way operations are performed in Airport Traffic Control Towers (ATCTs) today. Prior to the development of new air traffic management systems for use in ATCTs, it is necessary to know how, why, and when ATCT controllers currently use information about flights.

In the last two years, a handful of studies have been performed to identify comprehensive information requirements for the ATCT. Prior to these studies, the most comprehensive documentation on the use of information in Federal Aviation Administration (FAA) ATCTs was created by Computer Technologies Associates Inc. (CTA) in the late 1980s (Ammerman et al., 1987). CTA's voluminous task analysis provided flow charts depicting the activities, sub-activities, and tasks performed by controllers as well as the information objects controllers use to complete the tasks. Although it is likely that the fundamental tasks associated with ATC in towers have not changed much in the last 20 years, it is also likely that changes in the characteristics of air traffic and in the technology available to controllers have impacted aspects of how that air traffic information is used. This discussion will describe one of the recent studies performed to revisit and expand on the CTA ATCT task analysis to identify updated controller information requirements suitable for use in designing new systems.

Researchers at the FAA and Texas Tech University conducted an elaborate knowledge elicitation exercise with eight controller Subject Matter Experts (SMEs), using the FAA Academy's Adacel tower cab simulators. The SMEs controlled ten simulated ATC scenarios. The scenarios served as context that helped the SMEs recall the types of information they would typically rely on to perform the necessary tasks.

Scenarios were created by first identifying tasks listed in the CTA analysis that were associated with the largest numbers of information objects. The list of information objects related to the selected tasks were then cross checked against another list of information objects identified in a meta-analysis of the CTA task analysis (see Sethumadhavan, this panel) indicating which objects had the most relevance to ATCTs. The cross check was conducted to make sure that requirements could be collected for all the most relevant information objects. The air traffic events described in the CTA task analysis as initiating the selected tasks were identified. Researchers worked with ATCT SMEs to create realistic instances of these events that could be simulated using the Academy's simulated airport. These instances were apportioned between scenarios and were scripted into the simulation. The scenarios received several test runs using naïve SMEs and were tweaked to assure that the events played out as intended. The ten scenarios included the following events: precipitation, ground holds, noise abatement restrictions, runway and taxiway deviations, pilot runway requests, runway closings, pointouts to and from other ATC facilities, aircraft communication failures and other emergency conditions, takeoff cancellations, spacing conflicts, and reductions in visibility due to fog and night time operations.

SME access to ATC information was tightly controlled during the scenario runs. SMEs were allowed continuous access to an out-the-window view and a display of aircraft identification blocks that they could direct to be placed and sequenced. To access any other type of information, however, the SMEs had to orally request the information from a confederate. The confederate was able to provide the requested information (including graphics depicting the location on the airport surface or in the surrounding airspace of requested aircraft) by using a simulation control display. All requests for information were recorded and coded for analysis. Results are pending.

Mr. James M. Hitt, II

MR. JAMES M. HITT, II has more than 10 years of experience in the area of research, development, and assessment of human performance in the aviation domain. He has supported the FAA in the areas of advanced concept development and testing, air traffic metrics and system assessment, and human factors. In addition to his work with the FAA he has supported various DoD agencies, TSA, and NASA in human factors evaluations and methodology development. Jim serves on several editorial boards including Ergonomics in Design and The International Journal of Aviation Psychology, and has served as an ad hoc reviewer for the Human Factors Journal.

James Hitt's Position Statement

Airport traffic control towers (ATCT) perform an important function in the National Airspace System (NAS) in that many of the Federal Aviation Administration (FAA) safety and capacity goals depend on outcomes centering on the performance of tower controllers. To date, the design of tower cabs has remained the responsibility of each facility. No specific design guidance regarding the human factors characteristics of tower displays or the arrangement of displays within the tower cabs is readily available. Each tower has been viewed as a unique facility that evolved as funding allowed for equipage and as traffic demand grew. As a result, most tower cabs have a piecemeal design that placed equipment where there was available space. This process has been further exacerbated as additional equipment and displays have been added to the tower cabs over time. The design of most tower cabs does not support an efficient controller scan pattern, and there is not a clear understanding of tower controller information requirements.

The objective of the Tower Modular Design Analysis project is to develop a modular concept of ATCT display design that will support the FAA Air Traffic Organization - Terminal (ATO-T) system engineering concept to refresh the tower infrastructure. The purpose of this concept is to meet NAS safety and capacity goals that apply to the tower domain. This objective was met through a series of field data collection activities and analyses aimed at determining ATCT controller information needs performing various ground and local controller tasks at seven airports. It was our assumption that there is a core set of information needs for tower controllers that are common across all tower cabs. We used a series of task flow diagrams based on eight ground and local controller tasks to collect observational data from seven ATCTs. The observations focused on the information needs and information sources used by ground and local controllers.

The analysis of the observed ground controller's information needs and information sources converged with the results from the sequential scanning analysis. If you look at the most frequently occurring information used by the ground controllers, it is divided into the following areas:

- Where is the aircraft? (Aircraft Position)
- What are the aircraft's designation (Aircraft ID) and handling characteristics? (Aircraft Type)
- Where is the aircraft going to or coming from? (Destination, Flight Route, Taxi Route, Runway)

At the simplest level, the ground controller seeks to gather information to answer these three questions to successfully perform their duties. These data show that the ground controller accesses four primary information sources to answer the above questions. These include gathering data out of the tower cab window (OTW), from external communications (mainly with the pilot), flight progress strips, and ground radar. Results from the scanning sequence analysis highlighted several key points. First, ground controllers' visual scan consists primarily of a combination of looking out the tower cab window and using information from the flight progress strip (FPS). These two information sources were used in sequence six times more often than any other observed sequence – thus providing further converging evidence to support the notion of a core set of information needs. Second, ground controller's have a high dependence on data obtained looking out the tower cab window. This information source (OTW) was represented in five of six of the most frequently observed two sequence combinations – accounting for half of the 77% of the observed ground controller visual sequences.

The analysis of local controller information sources provided evidence that local controllers are also using a common set of primary information sources to complete their ATC tasks. The four most commonly used information sources (OTW, Surveillance Radar, External communication, and FPS) accounted for between 87-100% of the observed information source usage across the seven airports. If you were to include the ground radar data, which was only found at the five large airports, these five information sources account for 94-100% of the observed information sources used. Specifically, scanning sequences that involved OTW views, use of FPS, and use of surveillance radar were observed most frequently. These three sequences accounted for over 50% of the relative frequency of all scanning sequences.

The results supported our underlying hypothesis that there is a core set of information elements that are required by all ground and local controllers to perform their tasks. In fact, our analysis indicated a high degree of similarity between the core information needs for ground controllers compared to local controllers. These independent findings for both ground and local controllers were combined to conceptually design the information needs layout for a combined (ground / local) tower workstation.

To apply the findings of this work to a concept design level, we used a “tiered” approach concept to determine which information needs should be displayed in close proximity to one another. The notion of the “tier” is that information elements within a tier should be grouped together when possible and information elements associated with successive tiers (e.g., Tier 1 and Tier 2) are more closely related in an information needs requirement than information elements in non-successive tiers (e.g., Tier 1 and Tier 3). When examining the information elements within each Tier several characteristics were uncovered. Tier 1 information elements (aircraft ID, runway, aircraft type, and aircraft position) are currently displayed together in data block format in surveillance radar displays and in certain ground radar displays (ASDE-X). In addition, this information is also provided directly on FPS (although aircraft position data must be inferred from FPS, i.e. it provides aircraft sequence order). Tier 2 information elements mostly describe secondary information that ground and local controllers use to actually move aircraft from or to the airport surface. Tier 3 information elements are mostly based on status of airport conditions or traffic management initiatives. Traditionally, these are items that are briefed to controllers as they come on position. They can be either temporary (e.g. Traffic Management Initiatives or equipment outages) or longer time constraints (e.g., airport construction).

Ms. Arathi Sethumadhavan

MS. ARATHI SETHUMADHAVAN is a doctoral student in Human Factors Psychology at Texas Tech University under Dr. Frank Durso. She is involved in an FAA-funded project aimed at framing tower information requirements. Her Master’s thesis showed evidence that final radar performance was predictable from performance during nonradar training. Her work also involves studying information transfer in air traffic control shift changes. Her doctoral work is directed at cognitive factors in automation. She has a B.S in Computer Engineering.

Arathi Sethumadhavan’s Position Statement

Understanding the characteristics of information displayed, shared, and modified during the performance of air traffic control (ATC) tasks is important to gain a complete understanding of the demanding cognitive tasks performed by air traffic controllers. Information in any dynamic environment is characterized by at least eight characteristics (Durso, Sethumadhavan, Girotto, Morris, & Crutchfield, under review).

- Longevity: the length of time information is functionally available
- Support: the medium through which information lives in the tower
- Accessibility: the ease with which information can be obtained
- Timeliness: the availability of information when needed
- Benefits: the operational and psychological advantages of information
- Flow: the speed and direction of information travel within the ATC system
- Structure: the coexistence of multiple pieces of information
- Relevance: the importance of a piece of information

Identifying these characteristics of information would ultimately be used to generate a set of information requirements for aiding the design of ATC tower interfaces. Although all of these information characteristics are important in determining the nature of information in the ATC system, I will focus on the methodology for determining the relevance of information in ATC towers.

Relevance refers to how important a piece of information is in completing a task. Quantifying the relevance of information can be helpful in effective display design. For example, pieces of information that are more relevant should be more accessible in an ATC display than less relevant ones. Relevance of a piece of information is computed by taking into account three aspects of ATC tasks that use the information: the number of different tasks that make use of the information, the frequency of occurrence of those tasks, and the criticality of those tasks. Thus information that is required by several tasks that are very frequent and very critical can be considered more relevant than information that is required by fewer tasks of low frequency and low criticality. The relevance of information for the Ground controller, Local controller, and Flight Data/Clearance Delivery positions were obtained by analyzing the data gathered from an extensive cognitive task analysis of air traffic control conducted by CTA Incorporated.

Dr. Todd R. Truitt - Chair

DR. TODD R. TRUITT received a B.A. from the University of Kansas and an M.S. and Ph.D. in Cognitive/Experimental Psychology from the University of Oklahoma. He is an Engineering Research Psychologist in the Research, Development, and Human Factors Laboratory at the Federal Aviation Administration's William J. Hughes Technical Center. For 13 years, his research efforts have focused on cognitive factors in air traffic control. Todd is a private pilot and a veteran of the U.S. Army.

Todd Truitt's Position Statement

In this statement, we briefly document our approach to determine the information requirements for the most common tasks performed by Airport Traffic Control Tower (ATCT) ground and local controllers.

We sought information requirements to inform the design of new concepts for Electronic Flight Data (EFD) management. Overall, our approach was to integrate information into a single Electronic Flight Data Interface (EFDI). The EFDI provides controllers with only the most important flight data while still making all information available as needed. By integrating information such as airport status, aircraft flight data, aircraft position, and weather, we can reduce the controllers' need to shift visual attention between multiple information sources. Integrating information should also reduce the controllers' cognitive workload by making the needed information easier to find and use. To design an EFDI, we had to first understand the ATCT controllers' tasks and identify a set of information requirements.

We began the design process by conducting a literature review of ATCT research (Truitt, 2006b). Researchers have conducted relatively few studies (e.g., Ammerman, Becker, Jones, Tobey, & Phillips, 1987; Bruce, 1996) in the FAA ATCT domain compared to other air traffic domains. They have devoted even less time to understanding how the use of EFD may affect the controllers' ability to perform their tasks. If system designers wish to create new information displays that present the right information at the right time, then they must understand the ATCT controllers' job and how the controllers perform the various tasks. Designers must then present information that conforms to the controllers' mental model of the task. Only recently have researchers (e.g., Booz-Allen-Hamilton, 2006; Dattel, Johnson, Durso, Hackworth, & Manning, 2005) collected empirical data that start to fill the information requirements gap for ATCT controllers. Truitt's literature review also suggested that there are many differences between towered airport operations including equipment capabilities, staffing, and procedures (Truitt, 2006b). Therefore, it may be difficult to develop an EFDI that supports every type of ATCT operation.

After completing the literature review, we formed a working group made up of ATCT controllers, cognitive psychologists, and software developers. The working group employed a process based on the Bridge Methodology (Dayton, McFarland, & Kramer, 1998). The working group constrained the scope of the project by focusing on a single, prototypical airport configuration that one ground controller and one local controller could operate. We then selected the most common ATCT tasks as described in the task flows of Ammerman et al. (1987). The working group examined the most relevant four of the seven primary tasks (Perform Local Situation Monitoring; Resolve Conflict Situations; Manage Air Traffic Sequences; and Route or Plan Flights) and 24 of the 28 subtasks included for the local controller. For the ground controller, the working group examined three of the six primary tasks (Perform Ground Situation Monitoring; Control Aircraft/Vehicle Ground Movement; and Route or Plan Flights) and 10 of the 17 included subtasks. We examined each task flow to determine what information controllers needed, when they needed it, and why they needed it. We organized the information into task objects that included either arrival or departure aircraft. We found that each task object contained a number of task elements (i.e., essential information), many of which they shared in common. For arrival aircraft, the task elements included call sign, aircraft type, position, possession/control, reminder, hold short indicator, gate assignment, ground speed, and deviation/conflict indicator. For departure aircraft, the task elements included call sign, aircraft type, destination/first fix, proposed departure time, expected departure clearance time/delay, position, number in sequence, runway assignment, hold short indicator, Automated Terminal Information Service code, timer, ground speed, possession/control, reminder, and deviation/conflict indicator. The local controller needed the additional information for departure aircraft of altitude and heading, and Taxi-into-Position-and-Hold indicator.

Additionally, we used Ammerman et al's (1987) task flows to identify what actions controllers might need to manage the flight data.

Once we had all of the basic information requirements for the ground and local controllers, we formed an interface design team consisting of ATCT subject matter experts, a cognitive psychologist, and a software developer. The interface design team translated the information requirements into a graphical user interface (GUI) by first using low-risk prototypes. We used chart paper and sticky notes to model and test ideas quickly and cheaply, before engaging in software development. For example, we were able to quickly prototype and compare different list formats, data block designs, and aircraft representations.

Two different concepts emerged from the low-risk prototyping activities. The first concept integrates EFD with a surface surveillance system to provide real-time aircraft position information; this is the Integrated EFDI. The second concept presents EFD in a similar manner, but without the support of surface surveillance. Instead, the Perceptual-Spatial (P-S) EFDI uses a representation of the airport surface map as a visual anchor for the EFD. The P-S EFDI is an electronic version of the "shrimp boats" that controllers once used to track aircraft position without the aid of radar. The P-S EFDI also works as a backup system to the Integrated EFDI in the event that surface surveillance capability is unavailable.

Once the interface design team was satisfied with the initial design, the software developers began creating the functional GUIs of the EFDIs. We exercised each EFDI frequently during software development to refine the design and improve usability (see Truitt, 2006a, for a complete description of the design process and the resulting EFDIs). Finally, we conducted a formal usability test during a simulation exercise. The usability test provided data that showed the EFDI designs are viable and that they support the ATCT controllers' basic information needs.

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