ATC / AIR CARRIER COLLABORATIVE ARRIVAL PLANNING

Cheryl Quinn
Richard E. Zelenka

NASA-Ames Research Center
M/S 210-6 Moffett Field, CA 94035-1000, U.S.A.
(phone 650-604-5793, fax 650-604-0174, e-mail cquinn@mail.arc.nasa.gov)

Abstract

Air traffic growth and air carrier economic pressures have motivated efforts to increase the flexibility of the National Airspace System by changing the relationship between the air traffic control service provider and the air carriers, or system users. One of the most visible of these efforts is the U.S. government/industry "free flight" initiative, in which the service provider focuses on safety and cross-airline fairness, and the user on their business objectives and operating preferences, including selecting their own path and speed in real-time. A central tenet of the free-flight operating paradigm is collaboration between service providers and users on air traffic management decisions. Greater collaboration may help air traffic management on a daily basis by decreasing the severity of over-capacity rush periods at major airports. Collaboration would be particularly beneficial to airline "hub" operations, where off-schedule arrival aircraft can cause serious airport ramp difficulties, disruptions in airline schedules, and result in large economic inefficiencies. The NASA Collaborative Arrival Planning (CAP) project addresses some preliminary research issues concerning collaboration between air traffic management and the air carrier. The CAP project leverages the NASA/FAA Center-TRACON Automation System (CTAS), a fielded set of decision support tools that provide computer-generated advisories for both en-route and terminal-area air traffic controllers to manage arrival traffic more efficiently. This paper provides an overview of the Collaborative Arrival Planning project and a summary of the ongoing research in its two principal areas: real-time exchange of air traffic control (ATC) and air carrier information and incorporation of user preference information into ATC scheduling.

Introduction

Due to the continued increase in air travel and a shift toward "hub-and-spoke" operations by major air carriers in the United States, the National Airspace System (NAS) may be reaching its effective capacity. Daily peaks in the volume of air traffic can result in in-flight delays, holding or ground delays. Events such as severe weather or airport closures may result in aircraft diversions and flight cancellations that can impact hub-and-spoke operations for days. To address the capacity problems of the NAS, a NASA research initiative, the Advanced Air Transportation Technologies Program (AATT) is focused on developing "operational concepts and their associated decision support tools, procedures, and hardware systems to maximize safety, efficiency, and flexibility of operations in the NAS." [1] The program is comprised of ground-based air traffic management tools and some flight deck-based tools to support a move toward “free flight.” Free flight involves the removal of air traffic control restrictions and increased flight deck capabilities so that operators have the freedom to select their path and speed in real time. [2]

One ground-based system under development since the 1980s is the Center-TRACON Automation System (CTAS), a suite of decision support tools designed to effectively manage arrival traffic into a terminal area. CTAS (Build 2) is comprised of two major components: the Traffic Management Advisor (TMA) and the Passive Final Approach Spacing Tool (P-FAST). The TMA provides Air Route Traffic Control Center (ARTCC) Traffic Management Coordinators (TMCs) with time-based scheduling information to deliver a flow of arrival traffic into a terminal area that matches the current capacity of the facility.[3] TMA can also provide sector controllers with advisories indicating the amount of delay that each aircraft must absorb in order to achieve the desired flow rate. P-FAST increases airport throughput by providing Terminal Radar Control (TRACON) controllers with balanced runway assignments and landing sequence advisories. [4] The basic component of these tools is a set of 4-dimensional trajectory synthesis algorithms that use aircraft performance models and wind models to provide very accurate predictions of aircraft position over time. [5] TMA and P-FAST have been extensively evaluated in Fort Worth Air Route Traffic Control Center (ARTCC) and the Dallas/Ft. Worth TRACON respectively and have shown significant reduction in arrival delays and increases in throughput without adversely affecting controller workload.[4,6,7] TMA remains a primary decision support tool for daily traffic management at Ft. Worth ARTCC.

The CTAS TMA consists of two primary displays: the Timeline Graphical User Interface (T-GUI), and the Planview Graphical User Interface (P-GUI). The T-GUI displays arrival aircraft on a series of timelines referenced to arrival fixes into the TRACON or airport runway thresholds. For each aircraft, TMA can display estimated time of arrival (ETA), CTAS scheduled time of arrival (STA), per aircraft delay, and runway assignment (Figure 1). The P-GUI provides a planview display of arriving aircraft. The view is similar to a controller’s radar display with aircraft data tags presented on a map of the airspace (Figure 2). These displays are updated with every 12-second ARTCC Host radar update. The functionality of T-GUI and P-GUI has been developed with the participation of a variety of FAA controller personnel to ensure interface acceptability and usability.[4,6]

Figure 1. CTAS TMA Timeline Graphical User Interface.

Figure 2. CTAS TMA Planview Graphical User Interface.

The Collaborative Arrival Planning (CAP) project, an initiative within the NASA AATT program, is built on the concept that a great deal can be gained through collaboration between air traffic management and the users of the airspace. By providing air carriers with more accurate scheduling information and allowing them to have more input into flight path selection, airlines and cargo operators can more effectively manage both airborne and ground operations. The CAP Project investigates the concept of sharing information between air traffic control (ATC) and air carrier facilities, including airline operational control centers (AOC) and their airport ramp towers. Increased exchange of data between ATC and the air carrier is expected to improve air traffic management decision-making while providing improved efficiency of air carrier operations and greater scheduling flexibility.[8, 9]

The first phase of the CAP Project provides one-way flow of filtered CTAS TMA scheduling information to the AOC. The airspace user can then plan and make decisions based on more reliable estimates of arrival times. The next phase of the project involves transfer of air carrier information to CTAS, including aircraft departure times and weight information, which may help to improve the CTAS scheduling predictions. Later phases of the project will investigate two-way data exchange for assisting with individual aircraft arrival preference requests and incorporating fleet-wide user preferences into CTAS scheduling algorithms. This paper provides a summary of the results of the fielding of a CTAS TMA system at an airline AOC facility, and a description of future research efforts in two areas: the real-time exchange of information between air carriers and air traffic control (ATC), and the incorporation of user-preference information into ATC scheduling.

Current Research: ATC / Air Carrier Information Exchange

A first step toward greater air carrier and air traffic management collaboration is information sharing. ATC data on airport configuration, arrival scheduling, and runway assignments are expected to be of high value to air carrier operations. Such information can be provided by CTAS. Similarly, air carrier operational data, such as actual per-aircraft weight, accurate gate departure and take-off times, and aircraft-sensed wind information can be of benefit to ATC decision support tools. These types of data exchange between the air carriers and the ATC provider are being addressed and advanced through the CAP project.

ATC to Airline Information Sharing

The following sections focus on the results of a field evaluation of airline AOC use of CTAS-generated ATC scheduling information. The CTAS CAP Display System, a filtered "repeater" of the CTAS TMA system used by ATC was installed at the American Airlines System Operations Control (AALSOC) center in Ft. Worth, TX. Since CTAS Build 2 TMA is currently operational at Ft. Worth ARTCC and because American Airlines has a major AOC facility in the Ft. Worth area, the

Figure 3. ATC Coordinator and CAP Display System at AAL SOC.

AALSOC was selected for the initial field evaluation. At the AALSOC, the majority of requests and communication with air traffic control facilities are handled by an ATC Coordinator, so it was expected that the CAP Display System would be of the most value if installed at this position.

Primary implementation objectives for the experimental airline repeater included: ease of implementation, accurate repeating of the operational CTAS TMA at Ft. Worth ARTCC, and the guarantee of non-interference between the airline repeater and the operational CTAS TMA. To meet these objectives, a separate, complete CTAS TMA system was installed in parallel to the operational system at Ft. Worth ARTCC. One dual monitor workstation was provided to AAL's SOC facility to run GUI processes that display the CTAS information. This workstation was connected to the NASA North Texas CTAS field site network via four 128kbps ISDN lines, to provide the one-way communication necessary for the AAL-resident displays. This one-way slave-shadow configuration does not allow any interruption or manipulation in the airline repeater system to propagate back to the operational system.

A Memorandum of Agreement (MOA) between the Federal Aviation Administration, NASA, and AAL enumerated the restrictions and airline operating rules for the CTAS CAP Display System. Requirements imposed include the "scrubbing" of non-host airline identifiers on the aircraft tags and data blocks, and disabling the airline's ability to enter airport configuration changes. The digital data recording capability of the TMA system was disabled and all data is provided only as a display through the P-GUI and T-GUI displays. In addition, the host airline is also restricted from using CTAS to question the real-time decisions and operations of Ft. Worth ARTCC.

Human factors engineers worked with software engineering staff to ensure that the CAP Display System complied with all the requirements of the FAA MOA. The CTAS user interface was modified so that certain features were removed, or it was clearly indicated that features were disabled. Specialized training materials were prepared in order to help AALSOC personnel better understand the CTAS tools and how they assist with air traffic management at Ft. Worth ARTCC. Rather than use existing CTAS documentation, Quick Reference Guides for TGUI and PGUI were prepared to correspond to the modified functionality. AALSOC ATC Coordinators and dispatchers were also given a Quick Reference Card that provided step-by-step instructions for the most frequently used PGUI and TGUI functions.

Thirty-two ATC Coordinators and other AALSOC personnel were trained on CTAS and the use of the CAP Display System and were given a detailed, hands-on orientation. During an initial pre-operational evaluation period lasting three weeks, NASA personnel collected observations of system use and were available to answer questions. During this time, NASA observers were able to modify the TGUI and PGUI displays to help the ATC coordinators and dispatchers access CTAS scheduling information more easily. Four timelines were referenced to each of the four meter gates and two timelines were referenced to the four arrival runways (one runway per side of each timeline). A load graph was set up to show graphs of the anticipated demand into DFW, the CTAS scheduled traffic into DFW and the average per-aircraft delay. This display configuration allowed the ATC coordinators to locate a specific aircraft to determine its STA, quickly assess the average delay into DFW, or determine whether aircraft were in holding outside a meter gate. Data were collected on how CTAS information is used by AALSOC personnel and what information format is most useful for AOC tasks. Data were also collected to generally assess the benefits to the AALSOC of shared CTAS scheduling information. These data provide a better understanding of how CTAS scheduling information influences AOC information flow and its impact on operational decisions concerning holding and diversions.

Summary of Findings

Based on the observations conducted during the initial deployment and observations conducted after the repeater had been operational for about two months, CTAS TMA scheduling information was found to be beneficial to the AOC environment. AAL ATC Coordinators found that they made fewer phone calls to Ft. Worth ARTCC to check on delays into DFW. Dispatchers concerned with individual flights were able to use the system to find where an aircraft was and what its scheduled arrival time was likely to be. The more accurate arrival time predictions provided by the CAP Display System enabled AALSOC personnel to make better scheduling and fleet-planning decisions concerning flights arriving into their DFW hub. Results also show that more accurate arrival time estimates assist the airline in avoiding flight diversions to alternate airports, benefit airline strategic planning, and reduce the number of "status" phone calls from the airline to the FAA service provider.[10]

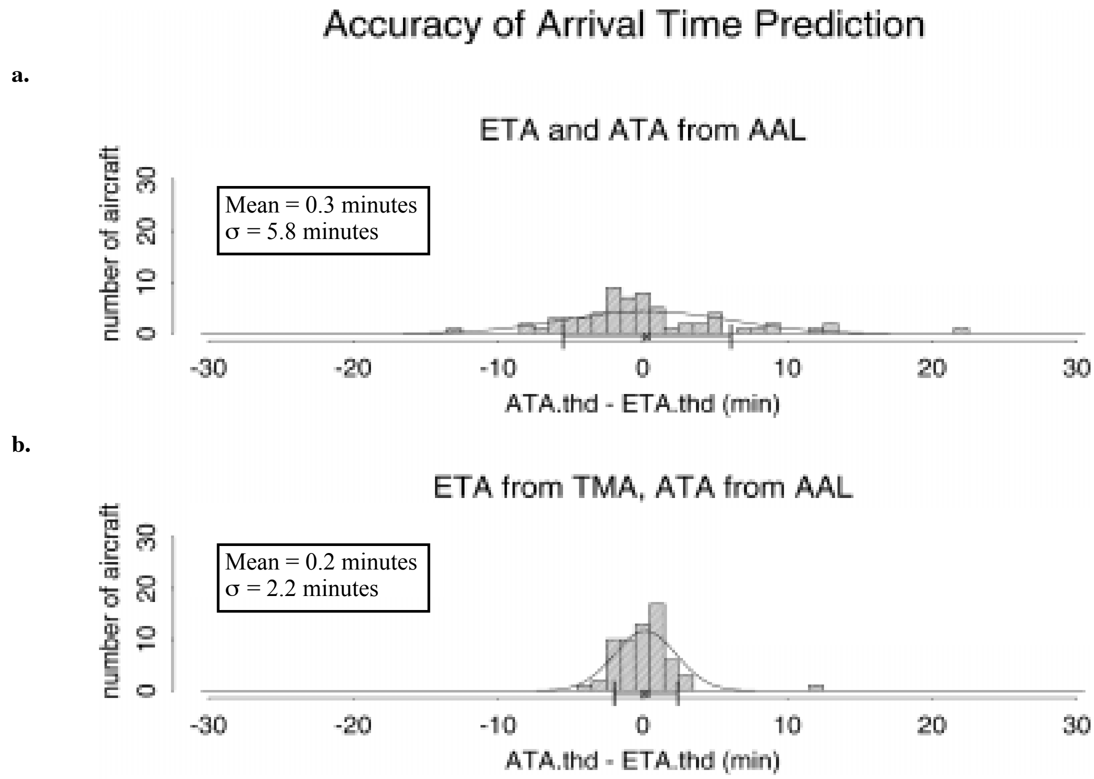
Time of Arrival Prediction Accuracy

Major airlines estimate the time of arrival for each of their flights by tracking time deviations from nominal flight plans. The flight plan, once updated to reflect the actual take-off time, is generally a good approximation of the en-route portion of a flight. However, any unexpected re-routing or delays can significantly alter the flight's landing or "on" time. Even if no en-route deviations occur to alter the nominal flight plan navigation fix times, a flight is typically subject to terminal-area delays (e.g. speed reductions, vectoring, holding) that significantly alter its "on" time. Such terminal-area ATC delays differ from day to day for each arrival rush, and are difficult for airlines to accurately predict.

Many airlines, including AAL, attempt to minimize the inaccuracies in their estimated "on" time by having their flight crews update their "on" time estimates during the flight, typically 30 minutes before landing. While helpful, such updating does not account for terminal-area ATC delays at the destination. At Ft. Worth ARTCC, the terminal-area delays are being calculated and assigned to *each* aircraft by CTAS TMA. TMA delays are assigned to match throughput to the current airport capacity, and because the controllers are vectoring aircraft to meet those times, the TMA scheduled arrival times are more accurate than the airline estimates.

Histograms of AAL time of arrival prediction accuracy versus those provided by CTAS TMA are given in Figures 4a and 4b. The prediction horizon is 30 min from actual time of arrival, using the crew-updated E ON prediction, if available (Figure 4a). CTAS TMA scheduled time of arrival (Figure 4b) is used for the same 63 aircraft at the same prediction horizon of 30 minutes.

The improved time of arrival prediction accuracy of CTAS TMA over typical flight plan/flight crew-adjusted airline estimates is shown in Figures 4 a and b. The values from the TMA-derived data are more closely centered around the mean (4 b) and those provided by AAL are more variable, resulting in a wider, more flattened distribution (4 a). The arrival time estimates from AAL have a 1-sigma accuracy



ETA reference time = ATA - 30 minutes   Data based on 63 aircraft

Figures 4a and b. Accuracy of American Airlines Predicted Arrival Times vs. CTAS Predicted Arrival Times

within 5.8 minutes of the actual arrival times, whereas the TMA-derived arrival time estimates have a 1-sigma accuracy within 2.2 minutes. These comparisons do not illustrate the impact that improved time of arrival predictions (and delay information) can have on individual flights. Improved time of arrival estimates, and associated terminal-area per-aircraft delay information assist AOC's in the management of potential flight diversions when confronted with otherwise uncertain ATC terminal-area delays.

Flight Diversions

Arrival aircraft approaching terminal areas are routinely delayed for separation or airport ATC constraints. Delays can be manifested as speed reductions, vectoring, or airborne holding. Aircraft are legally required to be dispatched with enough fuel to allow 45 minutes of airborne holding. Dispatchers typically request additional fuel based on their historical knowledge of en-route and terminal-area delays for each particular flight. As a cost saving measure, extra fuel beyond the 45 minute hold is not commonly carried unless severe weather or abnormal ATC delays are expected at the destination city. As such, arriving aircraft encountering unexpected, severe terminal-area delays must sometimes divert to an alternate airport.

When an ARTCC cannot absorb all required delay for a particular aircraft through speed reductions or vectoring, that aircraft is placed into a holding pattern. Generally, the first aircraft to arrive in the holding area is placed at the lowest holding altitude, and subsequent aircraft are placed at increasing altitudes. Each of these aircraft is then issued an Expected Further Clearance (EFC) time, which is the time at which the aircraft can expect to be released from holding and sent to a metering fix and into the airport. EFC's, which are typically issued by ATC during very dynamic, high workload periods are often conservative, inflated times, so the controller does not to have to re-compute the times or re-issue them for each aircraft. This practice is difficult for airline fleet operations, especially when an aircraft that is in holding is issued an EFC that would require the aircraft to divert due to fuel limitations (if the aircraft were actually held that long).

On several occasions the CTAS CAP Display System was used by AAL to assist in preventing diversions for flights into their DFW hub. These aircraft encountered unexpected terminal-area delays and were placed into a holding pattern. ATC issued EFC's ranging from 20 to 45 minutes; the flight radioed their dispatcher, concerned that fuel limitations would require a diversion to an alternate airport if they were held for the full duration of the EFC. AAL procedure requires the dispatcher to contact the AAL ATC Operations Coordinator to verify the actual, likely holding times with ATC. With the CTAS CAP Display System, however, AAL determined the average delays into DFW and the CTAS STA for the aircraft. These values indicated that the aircraft would be released from holding before the EFC expired, and the information was sent to the pilot, who elected to remain in the hold and land at DFW rather than divert.

AALSOC personnel also used the CAP display to proactively divert an aircraft before it would have been forced to divert, thereby saving fuel. The aircraft in question had just been re-routed by ATC to an alternate arrival corner. According to the CTAS P-GUI, the magnitude of the holding over the alternate arrival corner was such that the aircraft would exceed its fuel reserves. Given that the flight was already low on holding fuel, AAL diverted the aircraft to an alternate airport immediately rather than expend extra fuel in transit to another holding location, which would likely have led to a diversion.

In general, the cost of an aircraft diversion is a function of many variables, including equipment type, degree of coupling or connectivity between an airline's hub and feeder spoke flights, and how early in the daily flight schedule the diversion occurs. Costs associated with flight diversions described above include the direct operating costs of flying the aircraft to its alternate and back, those associated with holding aircraft on the ground, and lost future revenue from passenger ill-will caused by the excessive delays.[11] Such costs can be quite high, with estimates between $20,000 and $100,000 per diversion.

Strategic Fleet Planning

The CTAS CAP Display System has been found useful in airline strategic fleet planning, specifically in the areas of aircraft equipment move-ups and the previously described airline-initiated re-routing of aircraft through alternate arrival fixes. Aircraft equipment move-ups refer to aircraft substitutions as a result of the originally scheduled aircraft becoming unavailable. Circumstances forcing equipment move-ups include unexpected maintenance and aircraft diversions. The AAL Operations Coordinators attempt to shuffle available aircraft to minimize the impact of these delayed aircraft on their operations. A critical item required for such shuffling is the knowledge of what aircraft equipment is or will be available to build an alternate, smaller departing bank of aircraft. With the CAP display, the airline was able to locate aircraft and determine their arrival times to select potential candidates for schedule swaps. The CTAS information provided a new level of stability and efficiency to equipment move-up planning, and facilitated the recovery from the off-schedule operation.

TMA Repeater Impact on Airline Ramp Operations

In addition to proven benefit in the AOC environment, TMA scheduling information may also benefit airline ramp operations. Fueling trucks, baggage handlers, caterers and gate personnel are assigned to each gate based on the airline's estimated arrival times of each flight. These resources could be managed more effectively if ramp management personnel had more detailed, up-to-date schedule information and the expected landing runway. Both of these could be derived from a CAP Display System updated by a TRACON radar source.

An experimental fielding of a TMA repeater system at a ramp tower at DFW is planned and would provide insight into how CTAS scheduling information could benefit ramp operations, specifically, the impact of CTAS scheduling information on airline allocation of gate resources. AAL has suggested that CTAS-updated arrival information would be especially useful if it were integrated into their existing, highly-specialized ramp management software tools.

Future Research

Airline to ATC Information Sharing

The exchange of air carrier operational data to CTAS is planned and is currently being developed in a laboratory simulation environment. Actual aircraft weights, accurate gate departure and take-off times, and aircraft-sensed wind information can assist ATC automation decision support tools such as CTAS. Airline preferences, such as descent profiles/speeds and per-aircraft cost index (ratio of time and fuel costs), are either generically modelled (in the case of descent speeds), or are not considered (such as cost index).

Current CTAS algorithms assume aircraft parameters such as weight, engine performance, and aircraft performance based on generic models of a limited number of aircraft types, e.g. Boeing 757-200. While these assumptions are adequate for arrival trajectory synthesis, more accurate knowledge of aircraft weight and performance is essential for climb modelling. Providing airline-derived data to CTAS has the potential to improve the accuracy of the CTAS trajectory calculations, which could affect CTAS arrival scheduling. Improvements in arrival scheduling could benefit overall capacity by increasing arrival throughput. CTAS scheduling that takes into account airline cost index ratios for individual aircraft would likely yield airline operational efficiencies.

Once data are supplied by the airlines, the CAP project objectives will be to first evaluate the impact of these airline-supplied data on TMA and P-FAST as well as developmental CTAS tools in a laboratory setting. Should these data provide significant improvements in CTAS performance, more extensive data sharing efforts with other carriers would be explored.

Collaborative ATC / Air Carrier Tools

CTAS TMA scheduling is accomplished on a first-come-first-served basis. Delays are distributed among aircraft in such a way as to minimize delays to the system as a whole. This method of assigning delays to aircraft is objective and equitable; however there are times when the air carriers have distinct preferences regarding which of their aircraft receive delays. A given air carrier may have certain flights that are considered more important than others. For example, an international flight or a flight that carries a large number of connecting passengers would have a greater economic impact on the air carrier if the flight were seriously delayed. In certain cases, an air carrier can request that ATC do whatever possible to expedite a certain aircraft. In general, ATC will attempt to expedite the aircraft and may delay another of the same airline's aircraft to do so. Under no circumstances other than emergencies would ATC delay a second airline's aircraft to accommodate the first airline's preference. A long-range goal of the Collaborative Arrival Planning project is to be able to incorporate airline preferences into ATC scheduling. There are two efforts underway in the CAP project focusing on airline arrival preferences: the Tactical CAP tool and the Strategic CAP tool.

Tactical CAP Decision Support Tool

The first of these efforts is the Tactical CAP tool (T-CAP) which will be implemented in conjunction with the CAP Display System. This tool will enable an airline to submit a preference to ATC via the CTAS repeater system. The request would be sent to the traffic management coordinator at Ft. Worth ARTCC. From here, the request would be forwarded to the appropriate ARTCC sector.

The T-CAP system will be incorporated into the T-GUI of the CAP Display System. It will allow the airline to bring up a request form, enter the information and send it to ATC. ATC will process the request and forward it to the appropriate ARTCC sector. There may be advantages to sending the request to the TMC operating the CTAS system, because he/she may be able to handle the request more efficiently than the TMC who would normally handle the request over the phone. Through this effort, it will be possible to characterize the types of situations that cause an airline to ask for a preference, and understand how preference requests are handled in today's environment. These data will enable CAP researchers to make recommendations on how to incorporate airline preference information into ATC scheduling and how preference requests should be addressed in a more distributed decision-making (e.g., free-flight) environment.

Strategic CAP Decision Support Tool

The second effort, known as Strategic Collaborative Arrival Planning (S-CAP), investigates the possibility of developing new CTAS sequencing and scheduling algorithms which take into account airline preferences. Recent research in this area explores the feasibility of exchanging CTAS scheduling delays between pairs of aircraft as a means of accommodating an airline request for an earlier arrival. Carr uses fast-time simulation to demonstrate that it is possible to schedule an earlier arrival time for an aircraft by assigning an equivalent amount of delay to another aircraft from the same carrier. Results indicate that an aircraft could be scheduled up to five minutes earlier than the original estimated time of arrival (ETA) without impacting the scheduled delays of aircraft outside of the delay exchange pair. [12]

Another study currently underway focuses on a method of scheduling a bank of arrival aircraft according to a preferred order of arrival. The current CTAS scheduling algorithm sequences aircraft using a first-come-first-served (FCFS) method based on ETA at the runway threshold. The CTAS scheduling algorithm generates scheduled times of arrival (STA) at the runway that may delay aircraft in order to meet sequencing, separation and airport capacity constraints. In fast-time simulation, an alternative method of scheduling was used to schedule a bank of aircraft in a preferred arrival order. Results show that when compared with FCFS scheduling, the alternative method is often successful in reducing deviations from the preferred arrival order while resulting in little or no increase in scheduled delays.[13]

Future work will focus on improving the success rate of the new scheduling algorithms and gaining a better understanding of the effectiveness of the algorithms under various traffic conditions Another element to this research effort is to explore the costs of non first-come-first-served scheduling in terms of overall system delay increases and impact of delay exchange on controller workload.

Human Factors Issues Associated with ATC-Airline Collaborative Tools

CTAS tools have been developed and tested with a great deal of controller involvement. The T-CAP and S-CAP tools will follow the same user-centered approach, but for the first time will include air carriers as system users. The CAP Display System leveraged the existing TMA interface, which was modified to accommodate FAA MOA requirements. Thus, the system is intended for ATC, and it displays information in a manner that may not be suited to the airline's needs. For the initial evaluation, it was determined that a specialized airline interface for CTAS scheduling information was not necessary. The focus of the research was to determine whether the CTAS scheduling information was useful for AOC tasks, not to evaluate the existing interface. In fact, the airline would prefer that CTAS scheduling information be used to update their existing displays, which were designed specifically for the AOC environment.

The test deployment of the TMA repeater system has shown that the AOC environment can benefit from CTAS-derived scheduling information. It is also evident from observations that ATC and AOC have different goals when it comes to the routing aircraft. The AOC has a more global view of each specific flight and makes decisions for a flight from point A to point Z based on what is most beneficial for maintaining the air carrier's fleet-wide schedule. Air traffic, on the other hand, makes decisions based on what is best for all air traffic within the airspace on a sector by sector basis from A to B, B to C and so on. The sharing of ATC information with airline AOC is the first step toward achieving a common understanding of each group's goals and intentions, which will lay the groundwork for more extensive collaborative decision-making efforts in the future.

Throughout the tool development, the design tradeoffs between improving air carrier business choices and impacting controller workload will be carefully considered. In a tool such as T-CAP, specific requests are being made on an aircraft by aircraft basis. This tool will facilitate the request process that occurs in today's environment. As the capability for handling user preferences is incorporated into CTAS scheduling algorithms, it will be important to ensure that the controllers who are attempting to accommodate the requests are not overloaded. Efforts will be made to determine the impact of non first-come-first-served scheduling on controller workload and, if too extreme, further research will examine ways of providing advisories to the controllers to help achieve the preferred arrival schedule.

Concluding Remarks

Initial observations show that access to ATC scheduling information can be beneficial to the AOC by providing a more global picture of the air traffic coming into the airport. It provides the air carrier with information on expected delays and holding that might otherwise require phone calls to the ARTCC facility. By being able to see the amount of delay to be incurred by each aircraft, the air carrier can make informed decisions about when to divert aircraft during extended holding operations.

Based on discussions with Ft. Worth ARTCC and DFW TRACON personnel, there has been no adverse impact on FAA ATC operations as a result of the experimental fielding of the CTAS TMA Repeater at American Airlines SOC. In fact, results indicate a decrease in the number of telephone inquires to FAA facilities regarding specific aircraft in holding or concerned with excessive metering delays. As discussed, on the occasions when AAL used the CAP display to locate aircraft concerned with, or issued, long EFCs, AAL did not contact an FAA facility. Such a reduction in telephone inquiries, especially those that occur during the high workload periods of arrival rushes or severe weather, is viewed positively by FAA facilities.

Future deployment efforts will investigate the impact of precise estimates of arrival time on ramp and hub management operations. It is expected that precise arrival time estimates will allow air carriers to improve gate management operations through more efficient allocation of ground resources and personnel. The eventual goal of the CAP program is to incorporate user preferences into the CTAS scheduling algorithms. An air carrier can make business decisions about which flights are most important and these preferences can be accommodated if there are opportunities within the scheduling process. To this end, the CAP program will study the current methods for handling air carrier preference requests and develop ways of automating the requests; T-CAP will be the first step in this direction. The next step will be the investigation of the feasibility of performing non first-come-first-served CTAS arrival scheduling through S-CAP.

References

1. Ballin, M.G., Coppenbarger, R. A., Schleicher D.R. and Johnson, S.C., " Summary Overview and Status of AATT Program Development Activities," Flight Management and Human Factors Division NASA Ames Research Center, Moffett Field, CA, May 1997.

2. RTCA, Inc., "Final Report of RTCA Task Force 3: Free Flight Implementation," Washington, DC, October 1995.

3. Denery, D, Erzberger, H., "The Center/TRACON Automation System: Simulation and Field Testing," *Proceedings of the Advanced Workshop on Air Traffic Management,* October 1995, Capri, Italy.

4. Davis, T. J., Krzeczowski, K.J., Bergh, C., "The Final Approach Spacing Tool," *Proceedings of the 13th IFAC Symposium on Automatic Control in Aerospace*, Palo Alto, CA, 1994.

5. Erzberger, H., and Tobias, L., "A Time-Based Concept for Terminal-Area Traffic Management," *Proceedings of the 1986 AGARD Conference No. 410 on Efficient Conduct of Individual Flights and Air Traffic*, Brussels, Belgium, 1986.

6. Swenson, H.N., Hoang, T., Engelland, S., Vincent, D., Sanders, T., Sanford, B. and Heere, K., "Design and Operational Evaluation of the Traffic Management Advisor at the Fort Worth Air Route Traffic Control Center," *Proceedings of the 1st USA/Europe Air Traffic Management Research and Development Seminar*, Saclay, France, June 17-19, 1997.

7. Hoang, T. and Swenson, H., "The Challenges of Field Testing the Traffic Management Advisor in an Operational Air Traffic Control Facility," *Proceedings of the AIAA Guidance, Navigation, and Control Conference*, August 1997.

8. Perry, T., "In Search of the Future of Air Traffic Control," *IEEE Spectrum*, Inst. of Electrical and Electronics Engineers, New York, August 1997, pp.18-35.

9. Beatty, R. "Cooperative Problem Solving Between Airline Operations Control and ATC Traffic Flow Management," *Proceedings of the Airline Dispatcher's Federation Conference*, Airline Dispatchers Federation, Washington, D.C., 1996, pp. 204 - 208.

10. Zelenka, R., Beatty, R. and Engelland, S., "Preliminary Results of the Impact of CTAS Information on Airline Operational Control," *Proceedings of the AIAA Guidance, Navigation and Control Conference*, August 1998.

11. Irrgang, M., “Airline Irregular Operation,” Handbook of Airline Operations, McGraw-Hill, New York, NY, 1995, pp. 349 - 366.

12. Carr, G.C., Erzberger, H. and Neuman, F., “Delay Exchanges in Arrival Sequencing and Scheduling,” AIAA Guidance, Navigation and Control Conference, August 1998. AIAA-98-4478.

13. Carr, G.C., Erzberger, H. and Neuman, F., “Airline Arrival Prioritization in Sequencing and Scheduling,” *Proceedings of the 2nd USA/Europe Air Traffic Management Research and Development Seminar*, Orlando, FL, December 1-4, 1998.