THE CHALLENGES OF FIELD TESTING THE TRAFFIC MANAGEMENT ADVISOR IN AN OPERATIONAL AIR TRAFFIC CONTROL FACILITY

Ty Hoang* and Harry N. Swenson*
NASA Ames Research Center
Moffett Field, California

Abstract

The Traffic Management Advisor (TMA), the sequence and schedule tool of the Center/TRACON Automation System (CTAS), was evaluated at the Fort Worth Center (ZFW) in the summer of 1996. This paper describes the challenges encountered during the various phases of the TMA field evaluation, which included system (hardware and software) installation, personnel training, and data collection. Operational procedures were developed and applied to the evaluation process that would ensure air safety. The five weeks of field evaluation imposed minimal impact on the hosting facility and provided valuable engineering and human factors data. The collection of data was very much an opportunistic affair, due to dynamic traffic conditions. One measure of the success of the TMA evaluation is that, rather than remove TMA after the evaluation until it could be fully implemented, the prototype TMA is in continual use at ZFW as the fully operational version is readied for implementation.

Introduction

This paper describes the challenges of conducting a field evaluation of a modern air traffic management tool at an operational ARTCC (Air Route Traffic Control Center) facility. The tool is the Traffic Management Advisor (TMA). TMA is being developed by the NASA Ames Research Center and the FAA under the Center-TRACON (Terminal Radar Approach CONtrol) Automation System (CTAS) program.[1] The CTAS program was created to develop advanced air traffic control decision support tools. The test facility was the Fort Worth ARTCC or ZFW. The field test evaluated the functionality and usability of the human-computer interface, and the acceptance of the TMA tool by the ZFW facility. The test also validated the usefulness and acceptability of the TMA system by ZFW controllers and traffic management coordinators (TMCs). The paper details the operational impact TMA had on the ZFW facility. An in-depth analysis of the data collected during the test is presented in follow-up papers by Swenson[2], and Sanford and Lee.[3]

Air Traffic Coordination and Terminology

As a coordinator of air traffic management, a TMC estimates and predicts the demand of air traffic and a facility's capacity to absorb it. Demand describes the number of aircraft destined for a common airspace, be it a sector or an ATC (Air Traffic Control) facility, within a specified block of time. Capacity defines the maximum number of aircraft that can be safely accommodated and controlled within an airspace and during a given period. The capacity level of a facility is very dynamic and is heavily influenced by weather conditions, the availability of runways and meter gates, capacity fluctuations of adjacent ATC facilities, and the staffing level at the facility. A "rush" period refers to a period of time when the demand of traffic exceeds the handling capacity of the ATC facility. During a rush period, flow management methods are implemented to insure a safe and expeditious flow of air traffic. The flow control methods consist of any combination of the following techniques: aircraft route modifications, redistribution of time and distance separation between aircraft, speed control, altitude control, heading control (vectoring), and metering. Metering is the process of controlling aircraft so that they fly over or cross predefined locations at a scheduled time while maintaining sequence. The amount of time an aircraft has to incur to meet sequencing order and scheduling time is called a "delay absorption" or delay time.

The TMC develops and initiates flow management plans that mitigate the difference between the expected demand and estimated capacity of the facility. Designed as a strategic flow management tool, TMA helps TMCs work the congested traffic by providing a prediction of near-future traffic conditions. Other traffic management tools are also available to the TMC. A TMC uses historical knowledge of traffic, a spatially oriented display (a plan view display - PVD), and the Arrival Sequencing Program (ASP) tool to manage the flow of traffic. Prior to TMA, ASP was used as a metering tool. ASP generated metering times and delay values for use by both the TMCs and sector controllers.

* Research Engineer, Terminal Area ATM Research Branch

Knowledge gained from previous rushes gives TMCs a limited ability to predict future traffic conditions.

Controllers execute the flow management strategy prepared by the TMC. A controller monitors and controls traffic from a sector control station. Each sector station houses a PVD scope and various communication and information consoles. Sector controllers use the PVD to visualize aircraft position and spacing. The PVD displays a map of the sector airspace, a sequence list, and symbols for all aircraft within that sector. A sequence list is a table of text showing the preferred crossing time and sequence an aircraft is to be assigned. A controller then executes different tactical delay maneuvers so that the aircraft can reach the metering location at the desired time. Metering ensures air safety by delivering a consistent and predictable flow of traffic into the TRACON ((Terminal Radar Approach CONtrol) airspace. The implementation of flow control techniques such as metering typically imposes delays on aircraft to meet spacing restrictions, and to satisfy sequence and scheduled times of arrival (STAs).

An illustration of key airspace concepts used at an ARTCC facility is shown in Figure 1. The figure points out the fixes (outer meter fix, meter fix) used by the controller to meter traffic. In a metering situation, high altitude sector controllers merge arrival aircraft into streams of traffic over the outer meter fixes. The outer fixes are located on a designated National Airspace System (NAS) route along a constant radius arc sweeping outward from the meter fix. The arc represents a metering and hand-off horizon. A hand-off transfers the responsibility and safety of aircraft from one controller to another or between two facilities. Aircraft in the high sector are metered before they are handed-off to the low sector controller, at the low sector's speed and altitude preferences. A high sector controller may hand-off aircraft anywhere along the border of the arc and not necessary over a predefined outer fix position, provided that the low sector controller accepts the hand-off.

The low sector controllers merge the stream of aircraft from the high sector with other arrival aircraft entering the low sector. A meter gate is a pre-definedtransition zone where en-route or Center traffic is converged, sequenced, and spaced for transition into the TRACON airspace. Each aircraft entering the TRACON facility must satisfy altitude and speed restrictions by the time it crosses the meter gate. At ZFW, the meter fixes were located on an arc approximately 42 nmi from the DFW airport. The outer fix was situated on an arc about 60 nmi from the meter fix. (Note: The Dallas/Ft. Worth airspace has changed significantly since the field evaluation, but the TMA was successfully adapted to the new airspace and is still in operation today.)

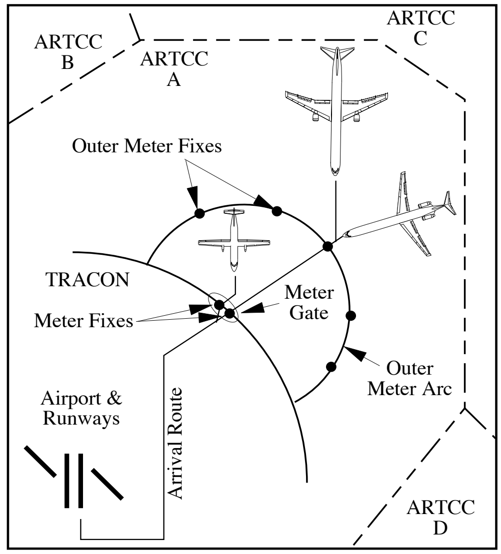

Figure 1: Key Metering Terminologies (not to scale)

<u>The TMA System at ZFW</u>

The TMA hardware at ZFW consisted of nine Sun Microsystems SPARCstation20 UNIX workstations. The workstations were linked together on a local area network. Running on the workstations were the various modules that constitute the TMA software.

The main software modules are the Route Analysis (RA), Trajectory Synthesis (TS), Dynamic Planner (DP), TMA Graphical User Interface (TGUI), the Planview GUI (PGUI), and the Communications Manager (CM). The RA generates aircraft routing information using a 3-dimensional path from the aircraft's current location to the meter fix and each eligible runway.[4] The TS calculates accurate 4-dimensional trajectory predictions using routing inputs from the RA and other variables like aircraft performance models, wind information, and initial and end-state conditions (altitude, speed, position).[4] TS produces vertical flight profiles, horizontal trajectories, and aircraft estimated times of arrivals (ETAs) at the outer fix, meter fix, and runway threshold. The DP module calculates optimal aircraft sequences and schedules to the outer arc, meter fix, and all eligible runways. DP applies capacity restrictions of wake vortex separation requirement, Airport Acceptance Rate (AAR), miles-in-trail separation to the TS-generated ETA times to produce conflict-free scheduled times of arrival (STA).[5] The TGUI is a time-based flow visualization tool, displaying ETA and STA sequences on vertical timelines. It is the primary tool of the TMC for interfacing with the TMA. The TMC enters flow control constraints into the TMA system via the TGUI.[6] A second flow visualization tool available to the TMC is the PGUI. It displays aircraft tracks, sequences and delay value information on a computer-generated airspace map.[7] Lastly, the CM module provides the underlying communication and messaging infrastructure that supports the other software modules.[8]

TMA in the Traffic Management Unit (TMU)

The TMU consists of a group of TMCs working in concert to coordinate all traffic within the facility. The TMCs are presented with two flow visualization tools, the PGUI and TGUI. These tools provide the TMC with different visual representations of the arrival traffic. The PGUI shows a planview of the Center airspace (Figure 2). Aircraft radar tracks within the Center boundary and as far as 400 nmi from the meter fix can be displayed on the PGUI. The PGUI allows the TMC to quickly and easily query aircraft information via aircraft datablock tags. Alternatively, the PGUI can display aircraft in the sequence-list format similar to that displayed on the PVD. TMA was used in place of an existing tool, ASP, which provided a sequence list format on the PVD. One of the conditions imposed by the TMCs was that this format be available in TMA as well.

The TGUI uses a timeline format to represent scheduling and sequencing information, and delay values for aircraft as far as 90 minutes from the meter fix estimated arrival time. Figure 3 shows a runway threshold timeline, showing aircraft from all meter fixes that are landing on runways 13R and 18R. The timeline is read from bottom to top, with current time (in minutes after the hour) at the bottom. As time elapses, the aircraft symbol and time value moves down the timeline. For example, aircraft AAL1712 has a threshold STA time of 13.5 minutes after the hour. It has two minutes of delay, and is landing on runway 18R.

Aircraft sequences are frozen as each aircraft's ETA passes the freeze horizon. The freeze horizon is a user-defined temporal parameter that determines when (in minutes, before an aircraft reaches the reference point, generally a meter fix) aircraft schedule, sequence and STA time should be fixed. Frozen sequences and delay values are displayed in a list format on the controller's PVD scope. The frozen schedules give the controller a stable list to control aircraft. From the TGUI timelines, the TMC can predict when and where a rush will arrive. The predictive capability permits the TMC to produce an effective traffic plan.

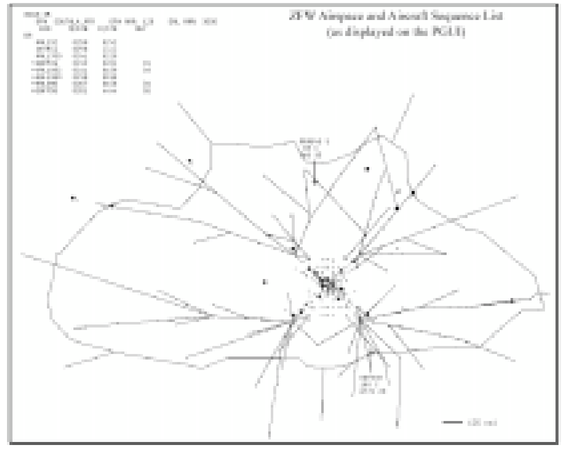

Figure 2: Aircraft Tracks and Sequence List, as displayed on the PGUI.

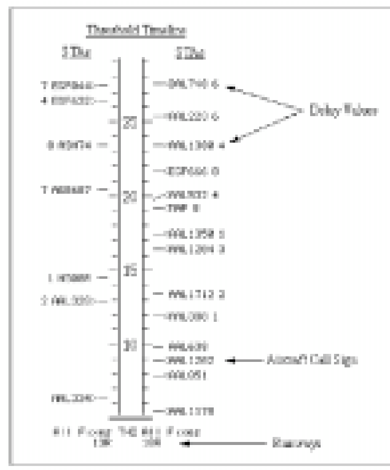

Figure 3: Threshold Timeline with Aircraft Tags and STA times.

In addition to traffic planning, ZFW and DFW-TRACON TMCs used TMA as a collaborative decision making tool. Because Center can provide TRACON with an accurate characteristic of the impending rush traffic, the TMCs can negotiate an AAR that is acceptable to both facilities.

TMA at the Radar Positions

Use of TMA had minimal impact on the controllers. Under ASP, the STA metering times and delay values were displayed on the controller's PVD in a table-like format called a sequence list. TMA emulated the format of the ASP sequence list to display advisory times. From the controller's perspective, the TMA-generated sequence list varied little from the ASP list. The variation included the outer arc reference for high altitude controller and tactical sequence control.

For all intents, TMA usage was made transparent to the sector controllers. The only indication given to the controller is a header message indicating TMA was operational instead of ASP. The header message, located at the top of the sequence list, indicates the airport arrival rate (AAR) along with a text message displaying "CTAS".

Scope of the Field Evaluation

Engineering Evaluations

The field evaluation was conducted in two stages, one week of engineering evaluation and four weeks of operational evaluation in which quantitative and qualitative data was gathered. The primary objective of the engineering evaluation was to establish a secured two-way (bi-directional) communication link between the ZFW Host computer system and the TMA system. The two-way communication allowed for the broadcasting of TMA advisory times onto the controllers' PVD. Operational data collection depended on the successful completion of the engineering evaluation.

Other testing criteria were assessed during the engineering evaluation period. Accuracy of STA times and delay values at the outer fix and meter fix were scrutinized. The sequencing of arrival aircraft to each meter fix and runway was checked for efficiency. Another goal of the evaluation was to check for assurances that all available landing slots were occupied and loading of the runways was balanced.

Operational Evaluations

The objective of the second stage of the evaluation was geared toward the collection of engineering and human factors data. Operationally, TMA metered multiple rush traffic throughout the day. An in-depth analysis of the engineering data is detailed by Swenson.[2] Engineering data collected during the operational period were very similar to those collected during the engineering evaluation period, i.e., aircraft sequencing and accuracy of STA and delay values. Human factors assessments are addressed by Sanford and Lee.[3] Human factors issues included human-computer interface and workload factor as perceived by both controllers and TMC during rush periods.

ZFW rush traffic hours were known to occur at: 8, 9, and 11 AM, 12 Noon, 1, 2, 5, and 7 PM local time. Due to resource constraints, but for quantitative comparisons, TMA was used to meter two occurrences of the same rush hour traffic. Table 1 shows the rush traffic that was recorded during the engineering and operational evaluation periods. When time permitted, additional shadow files (see "Shadow Data Collection") were collected to expand the shadow-file database. A total of 39 operational periods were recorded. As shown, TMA metered multiple rush hours throughout the day.

Table 1. Field Evaluation Test Matrix

Date / CST	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Engineering Evaluation																		
6/10/96																	M	
6/11/96															M			
6/12/96				B				B										
6/13/96									B				B					
6/14/96					M													
Operational Evaluation																		
6/17/96														M				
6/18/96													M	B				
6/19/96			M		M													
6/20/96		M	M			M	M	M										
6/21/96			M															
6/24/96						M		M			M		M					
6/25/96		M		M		M	M	M										
6/26/96		M	M			B												
6/27/96						M		M										
6/28/96			M															
7/15/96																		
7/16/96		M			M		B	M										
7/17/96		M	M	B	B	B	M											
7/18/96					M			M			M							
7/19/96			M				M											
7/22/96									N		M			M				
7/23/96									NW			N		N				
7/24/96					M			MI	N									
7/25/96																		
7/26/96																		

Legend:

- CST - Central Standard Time (local time)
- B - Baseline data recording (shadow data)
- I - Recorded an unscheduled rush
- M - Scheduled metering period (using TMA)
- N - Rush failed to materialize during scheduled period, data not recorded
- W - Weather affecting "normal" traffic resulting in abnormal traffic pattern

The Data Set and Recording

For each of the 39 recorded rushes, an engineering and a human factors data set was recorded. The TMA evaluation team held a debriefing after each rush period to clarify any system and traffic anomalies encountered during that rush. Together, the two data sets formed a complimentary view of how traffic was controlled, the workload involved in controlling it, and the factors that influenced traffic management decisions.

The engineering data set consisted of three data files: a radar file, a TMA data file, and a log file. The radar file records ground track history, flight plans, routing information, and TMA-Host messaging information. The TMA system is capable of automatically recording an extensive amount of data, 151 different variables. Example data include: aircraft position, ground and air speeds, beacon code, call sign identifications, flight plan, winds aloft information, and ETAs and STAs to various fixes.

The log file documents all information pertinent to each evaluation period not included in the radar file or accessible by the TMA data file (i.e., real-time data recordedmanually). The types of data recorded include airport weather condition, visibility, airport flow configuration and acceptance rate, and the number of available runways. Additionally, any anomalous traffic characteristics, strange aircraft behavior, and traffic resolution procedures were recorded.

Questionnaires were used to collect human factors data. Controllers and TMCs were asked to complete the questionnaires after each metering period. Controllers rated TMA features such as aircraft sequence, the aircraft swapping function and the quality of the advisory times. The questionnaires gave controllers an opportunity to express their opinion about the TMA system and its impact on their workload level. The TMCs rated the performance and acceptability of the TMA system. TMC-related workload level and ease-of-use of the human-computer interface were addressed in the questionnaire.[3] Initial responses from controllers and TMCs showed a favorable inclination toward the usage of TMA to meter traffic.

A Sample Rush Period

Ground track history of a typical noon hour rush is plotted in Figure 4. The airport arrival rate was set at 108 aircraft per hour for this particular period. Note the four convergent streams of traffic located near the center of the picture. The convergence represents the transition of aircraft from the Center into the TRACON airspace. Each of the traffic streams delivers aircraft over a meter gate. (Note: the scale for Figures 4 and 5 is in nmi).

Figure 5 shows aircraft tracks inside the TRACON airspace, from the airport out to the meter gates. This is a close-up of Figure 4. Starting from the upper right (North-East) and proceeding clockwise, the metering gates at DFW were: Blue Ridge (BUJ), Scurry (SCY), Acton (AQN), and Bridgeport (BPR). The parallel runways are located in the middle of the picture. A south-flow landing configuration is readily discernible.

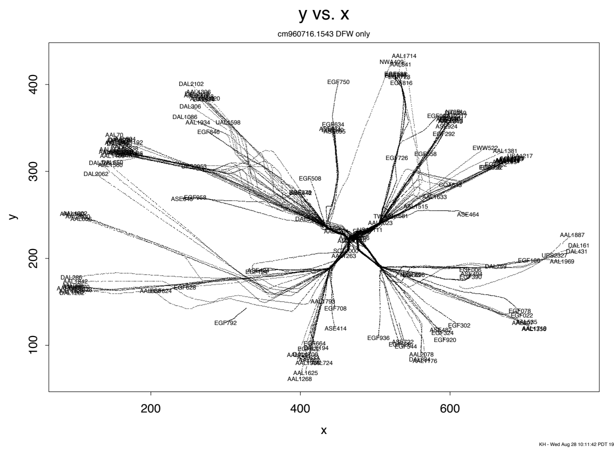

Figure 4: Aircraft Tracks in Center Airspace

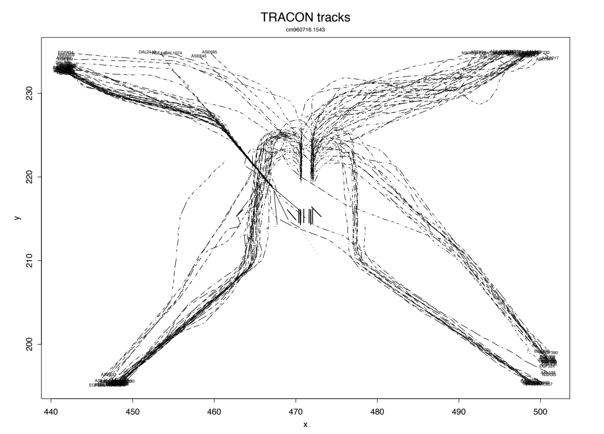

Figure 5: Aircraft Tracks in TRACON Airspace

Figure 6 plots the predicted aircraft throughput (flow) as a function of time. The throughput peaked at 30 aircraft about 16:30 UTC (or 17,000 seconds after TMA started). The TMA aircraft-count parameter was set to count aircraft within a 10-minute sliding window. With 30 aircraft per 10-minute interval and at an AAR of 108, which is equivalent to 18 aircraft per 10 minute interval, demand easily exceededairport capacity. The figure plots arrival aircraft for both DFW (Dallas/Ft. Worth - solid line) and DAL (Dallas Love Field - dotted line) airports. Currently, only TMA generated scheduling times and sequences for aircraft landing at the primary airport (DFW) are used and not at any satellite airports (i.e., DAL).

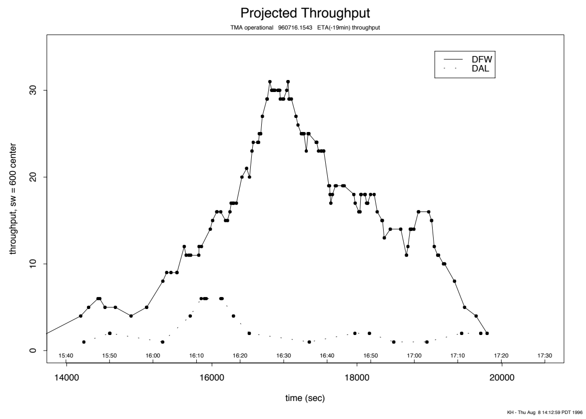

Figure 6: Projected Airport Throughput Diagram

The number of aircraft landed during this rush period is graphed in Figure 7. The figure identifies three distinctive flow characteristics. At the beginning of the rush, a front-loading period is established, followed by a sustained period where TMA scheduled the proper number of aircraft to meet the desired airport arrival rate of 108 per hour. The rush ended with a drop-off period, where demand dissipated. "Front-Load" allows TRACON to land more aircraft than the AAR, at the beginning of the rush when a higher capacity is allowed. The amount of traffic that exists before front-loading is comparable to the drop-off period. Figure 7 represents a typical rush period with front loading.

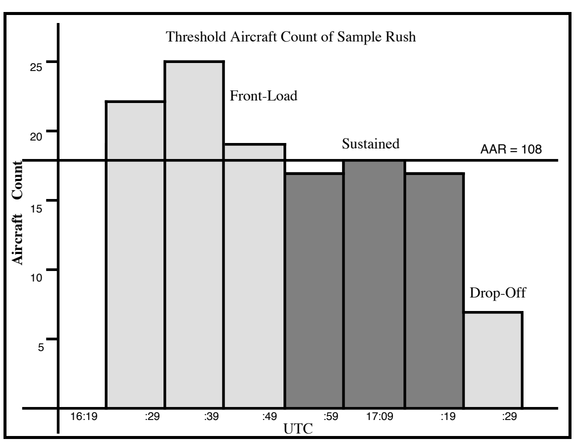

Figure 7: Threshold Aircraft Count

Challenges and Limitations

Many challenges were encountered during the pre-evaluation and formal evaluation period at ZFW. The challenges and limitations varied in scope, ranging from system checkout to training of facility personnel, and installation of the system at the test site. In the field, procedures of conduct were developed for operational use and data collection.

Challenges Prior to the Field Evaluation

Human-in-the-Loop Computer Simulation

Extensive preparatory work was done to support the field evaluation. The human-in-the-loop computer simulations employed pilots and controllers to evaluate the TMA software. Controllers used TMA-generated sector airspace maps to give advisories to the pilots, who flew simulated aircraft that had six degrees of freedom dynamics.[9] The simulations duplicated most controller and pilot interactions and exercised most TMA functions. However, the human-in-the-loop simulations conducted at NASA Ames could not simulate the two-way, bi-directional communication protocol that takes place between the TMA and Host Computer System (Host) at the Center. The testing of the two-way communication was performed at the FAA Hughes Technical Center (FAATC) in New Jersey.

The FAATC facility has the capability to duplicate the operational environment at ZFW. The simulation permitted interaction between the Host computer, TMA, and controllers. FAATC simulations examined controller issues, verified non-interference, and allowed for an overall system checkout. Issues that controllers looked for included the quality and usefulness of the human-computer interface, and testing of new controller-specific functions. Checks for non-interference compliance were extensively conducted to insure communication integrity with the Host. In two-way mode, the Host transmits TMA-generated times to be displayed on the PVD scope of all metering sectors. Without exception, TMA had to gain non-interference approval from the FAATC before operational evaluation at ZFW.

Shadow Data Collection

A series of live traffic recordings or "shadow" data files were collected before and during the field evaluation. These shadow files formed the baseline model against which the data collected during field evaluation was to be compared. The shadow files captured STA time, delay value, and aircraft sequence data that were generated by the ASP metering program. These files show the traffic handling capability at ZFW under ASP. A method of assuring a statistical match between the baseline and field test data set was to record a large sample of baseline data. It was anticipated that matching data sets could be found between similar rush periods.

Challenges at the Field Site

TMA System Requirements

In support of the field evaluation, the ZFW facility created a new traffic management area called the CTAS-

TMU. The CTAS-TMU used TMA to construct a plan to meter traffic. When the CTAS-TMU is operational, the existing ZFW TMU acts as a secondary unit. In the event of a CTAS-TMU emergency, the ZFW TMU would supersede as the primary TMU. The CTAS-TMU area housed TMA and the supporting hardware (Figure 8).

Five Sun SPARCstation20 workstations, video displays, a PVD, and the TMC communication station were located in the CTAS-TMU area. Five additional UNIX workstations were situated at another location, but all were connected on the same network. The compliment of nine workstations is considered a minimal hardware configuration required for operational use and to conduct the field evaluation. The TMC monitors all arrival traffic via the PVD, PGUI, and TGUI displays. The communication station allows the TMC to contact other TMCs, sector controllers, and ATC facilities.

Figure 8. CTAS-TMU, TMA engineer (background), and TMC with PVD scope (foreground).

Personnel Requirements

A team of eight ATC and TMA specialists conducted the field evaluation. The team consisted of two ZFW TMCs, a National Air Traffic Controllers Association (NATCA) representative, three research engineers, and two human factors specialists. By using TMA to guide traffic, the TMCs evaluated the performance of the system. The NATCA representative acted as a liaison between the controllers at the sector control stations and the evaluation team at the CTAS-TMU during the testing. The engineers ensured an orderly field evaluation, monitored the health of the system and collected engineering data.

Arrangements were made by the NATCA representative with the local union chapter to allow the human factors specialists to monitor and collect data at the various sector stations. After each observation period, the human factors specialists handed out and collected questionnaires from controllers and TMCs. Disruptions to the controllers were minimized by using the NATCA liaison as a point of contact between the controllers and the evaluation team. When testing certain TMA functionalities, the arrangement with the controllers was also made by the liaison.

Although not a part of the evaluation team, the TMCs at the TRACON facility also assisted with the field evaluation. They were instrumental in providing feedback to the evaluation team. The feedback included comments on the quality and quantity of aircraft delivered into the TRACON airspace. This allowed the ZFW TMCs to update their traffic plans, and to adjust the flow characteristics of subsequent rush periods.

Operational Procedures

An operational procedure for the field evaluation was developed with inputs from ZFW management and controllers. The procedure described when, who, and under what conditions the TMA system should be engaged to meter traffic. These procedural limitations were necessary to ensure air safety. A fundamental constraint stated that under no circumstances shall the TMA system interfere with the Host computer system. In a worst case scenario, where the TMA system malfunctioned while metering traffic, a safety procedure was developed that allowed the ZFW facility to revert back to the ASP program for metering advisories. Several simulations of this procedure showed that it took less than one minute to accomplish the transition. The ZFW facility found the transition time acceptable. Although this was an unlikely scenario, the test team had to demonstrate this capability to gain the confidence of the personnel involved and ZFW management.

The operational procedure required that the engagement of the TMA system be conducted under the supervision of a TMC who was trained on the TMA system. The TMC would determine if metering was necessary, when to meter, and the duration of the metering period. Ultimately, the TMC is accountable for flow control decisions that affect all aircraft within the facility's airspace. If necessary, the TMC had the ability to override any and all TMA generated advisories. In addition, a TMA engineer was required to be present during each metering session to monitor the health of the system.

The evaluation also stipulated that the testing exact minimal impact on normal facility operations. As an example, prior to engaging the TMA system, the air traffic automation staff (who maintains the Host computer) was asked to enable two software "switches" that allowed TMA to communicate with the Host computer. The same switches were used to disconnect TMA from the Host computer. The toggling of the switches could be accomplished by one person and required little supervision by the automation staff, thereby minimizing facility support of TMA.

Training Issues

To operate TMA efficiently and effectively, TMCs unfamiliar with TMA were required to attend a training session. The training required one day of classroom instruction and several weeks of on-the-job training (OJT). The new TMCs were trained by a TMC on the evaluation staff. The classroom instruction introduced the trainees to TMA capabilities. The OJT allowed the trainees to exercise TMA functionality and varied in duration for each TMC.

The TMCs were not required to get formal certification on the TMA system, but it was critical that they got fully acquainted with the capability of the system. Decisions made by the TMC have a rippling effect throughout the facility, affecting high sector and low sector controllers, and the delivery of traffic into the TRACON facility.

As mentioned previously, training of sector controllers on the interpretation of the sequence list was minimal. The similarity of the format of the ASP vs. TMA lists required little controller training and expedited the acceptance of the TMA system. The minimal requirement in training was significant, considering the number of controllers working at the facility. Many controllers work the rush traffic, with up to three controllers per sector and a minimum of eight sectors. Throughout the evaluation period, TMA was used to meter traffic during different hours of the day with at least one change of controller work-shift. Each work shift change has the potential to introduce new variables into the test system, in terms of aircraft handling preference and style. Nevertheless, it was critical that the controllers were comfortable with the sequence list and employed it to controlled aircraft to meet STA's.

In addition to the sequence list, controllers were trained on the use of a new aircraft handling technique requested to be included in TMA by the controllers. The aircraft swapping function allows the controller to swap the sequence of two similar type aircraft flying over the same meter gate (i.e., two jets crossing the Bridgeport gate). The swapping of sequences gives controllers an additional aircraft handling technique, in addition to speed, altitude and vector.

Data Collection Procedure and Conduct

As the anticipated rush period approached, the atmosphere inside the air traffic facility became more tense. In this high stress environment, the evaluation team collected engineering and human factors data. The high pressure environment increased the complexity of data gathering.

The collection of data was very much an opportunistic affair. Although the test matrix provided a data gathering schedule, the behavior of the rush traffic was uncertain. An example of this opportunistic activity can be seen in the data collection made on July 23rd (see Table 1). Three data recording periods were planned for that evening but the rush traffic did not appear. Earlier in the day, a thunder storm encroached on the Dallas/Ft. Worth area and forced traffic to divert to adjacent ATC facilities. The diversion dispersed enough aircraft that the anticipated 6:00 and 8:00 PM rushes never materialized. Whereas on July 24th, a rush period formed an hour earlier than the scheduled 3:00 PM rush. By the time the 3:00 PM hour arrived, there was not enough traffic to require metering. The test team was alert to traffic conditions and data collection was initiated when warranted.

The diverse traffic collected in the data files was classified using attributes common to each rush. The data file contained information such as airport flow configuration, AAR, weather conditions, and delay classification. From the amount of delay imposed upon the aircraft in the system, the rush traffic could be classified as light (delay less than 5 minutes), medium (less than 15 min.) or heavy (greater than 15 min.). These attributes were used to catalog and classify the type of rush traffic, as well as database search parameters. The same cataloging method was applied to the shadow files. Although each recorded rush was unique, the cataloging scheme provided a means of comparing similarly configured operational and baseline data files.

At the sector stations, the objective of the data collectors was to collect accurate log of traffic while keeping controller-interrupts to a minimum. To insure accuracy, it is preferable to document traffic situations as they unfold rather than from memory. Clarification of traffic anomalies was more accessible at the CTAS-TMU than at the sector stations, due to high controller workload. Human factors data were collected at randomly chosen sector stations and at the CTAS-TMU, where engineering data was also collected.

Concluding Remarks

Many challenges were encountered in preparation for the TMA field evaluation at ZFW, from the construction of the baseline database to the non-interference testing at the FAATC. These challenges included: installation of the system at the test site, training of the TMCs and controllers, development of operational procedures including fall-back plans in the event of a TMA failure, matching the display format of a previously used metering aid and establishing data collection protocols. The hurdles were overcome via a high degree of coordination and cooperation between ZFW management, controllers, and the TMA evaluation team.

The field evaluation itself is a challenge. Unlike the controlled environment of a simulation test where specific cases can be created and arrival patterns can be duplicated exactly, gathering data in the field is strictly opportunistic. Matching ensembles of data sets collected with TMA in use to “equivalent” rush periods when TMA was not in use was a painstaking process, involving developing a categorization based on rush attributes. Careful collection of human factors data at radar positions involved creation of data collection forms, completion of controller questionnaires as well as intensive observation of the rush period.

Overall, the field evaluation was considered a tremendous success. The field evaluation imposed minimal impact on the hosting facility and provided valuable engineering and human factors data. The success of the project was realized when the ZFW facility requested to have TMA operational during all metering periods.

Acknowledgments

Participation by the ZFW and DFW-TRACON facilities, FAA William J. Hughes Technical Center and the FAA CTAS Program Office as well as various FAA contractors made this field evaluation a successful venture. Special thanks go out to the Fort Worth Center TMCs, Danny Vincent, Tommy Sanders, and Dutch Daugherty, our NATCA representative, Jim Karlovich, and DFW-TRACON TMC - Jerry Saunders. Their participation and enthusiasm helped see this project through and greatly eased our transition into ZFW and the air traffic control environment.

References

1. Erzberger, H., Davis, T.J., and Green, S.M.: "Design of Center-TRACON Automation System." Proceedings of the AGARD Guidance and Control Panel 56th Symposium on Machine Intelligence in Air Traffic Management, Berlin, Germany, 1993, pp. 11-1 - 11-12.

2. 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 Ft. Worth Air Route Traffic Control Center”, to be published as a NASA Technical Memorandum.

3. Sanford, B., and Lee, K.: “Traffic Management Advisor: An Operational Human Factors Evaluation”, to be published as a NASA Technical Memorandum

4. Davis, T.J., Krzeczowski, K.J., and Bergh, C.: “The Final Approach Spacing Tool", Proceedings of the 13th IFAC Symposium on Automatic Control in Aerospace-Aerospace Control, Palo Alto, CA, 1994, pp. 70-76.

5. Wong, G.: "The Dynamic Planner", to be published as a NASA Technical Memorandum.

6. Air Traffic Management Branch: "TMA Procedure Summaries, Release 4.2.1t", NASA Ames Research Center, Moffett Field, CA, July 1995.

7. Air Traffic Management Branch: "Traffic Management Advisor, PGUI Addendum, Release 4.3.0t", NASA Ames Research Center, Moffett Field, CA, August 1996.

8. Air Traffic Management Branch: "Two Way Interface (TWI) Developer’s Guide, Preliminary Release", NASA Ames Research Center, Moffett Field, CA, January 1997.

9. Weske, R.A., and Danek, G.L.: "Pseudo Aircraft Systems: A Multi-Aircraft Simulation System for Air Traffic Control Research", Proceedings of the AIAA Flight Simulation Technologies Conference, Monterey, CA, August 1993.