Performance Metrics
Results to Date

June 2000
Report

INTRODUCTION

This document presents the methodology and results to date of the Free Flight Phase 1 (FFP1) Operational Impact Evaluation. The analyses have been performed as a logical evolution of the FFP1 Metrics Team's August 1999 report, "Free Flight Phase 1 Performance Metrics: *An Operational Impact Evaluation Plan,*" (Metrics Plan). The Metrics Team is led by Dave Knorr (AOZ-40) and includes analysts and controllers from several Federal Aviation Administration (FAA) organizations, MITRE's Center for Advanced Aviation System Development (CAASD), TRW/SETA, GEMS Inc., CALIBRE Systems, Inc., and TASC, Inc.

Most of the metrics identified in this June 2000 report were originally in the FFP1 Metrics Plan. However, we have added additional operational metrics highlighting unanticipated benefits from the FFP1 capabilities. Much of the discussion provided in this document as well as many of the charts and graphics have been presented to FFP1 Stakeholders in past meetings and conferences.

Highlights from the analyses to date (June '00) are as follows:

CDM: More than 7 million minutes of scheduled delay avoidance through schedule compression

SMA: Avoidance of 3-5 diversions per week during inclement weather

pFAST: Increase of more than 5 operations per rush at Dallas/Fort Worth International airport (DFW)

TMA: Increased airport acceptance rates at DFW

URET: Increased direct routings and reduced altitude restrictions

Please note that the results to date are for the pFAST, TMA, and URET prototype systems only. FFP1 will deploy an additional five sites for pFAST and URET and seven sites for TMA by 2002. The Metrics Team will prepare updates to this report on a semiannual basis. Additionally, the Metrics Team will continue to provide these updates to Stakeholders as appropriate.

This document is divided into the following seven sections:

1. Safety
2. User Request Evaluation Tool (URET)
3. Passive Final Approach Spacing Tool (pFAST)
4. Traffic Management Advisor (TMA)
5. Collaborative Decision Making (CDM)
6. Surface Movement Advisor (SMA)
7. Baselining for future FFP1 Implementations.

The first section provides an update on safety metrics. The focus of FFP1 is to provide operational improvements in delay reduction and increased capacity while maintaining a high level of safety. Safety metrics have been established in collaboration with

Stakeholders and focus on changes in operational errors (OEs) or operational deviations (ODs) associated with FFP1. While it is expected that each FFP1 capability will maintain or improve safety, the metrics will provide a mechanism for assuring the safety goal is met. The FAA has developed a set of safety standards that define spacing between multiple aircraft and airspace. To date there have been no known safety related incidents associated with FFP1 capabilities.[1]

It should be pointed out that the use of safety metrics to measure FFP1 tool performance are only the last phase in assuring that a high level of safety is maintained with the FFP1 capabilities. Safety is an integral part of the design, test and evaluation, and implementation phase of each tool.

A comprehensive analysis of URET at Indianapolis (ZID) and Memphis (ZME) centers makes up the second section. Since February 1999, the FFP1 Metrics Team has been examining the use of URET at these locations on a monthly basis. The results provided in this section are updated each month for the FFP1 monthly program reviews and periodic Stakeholder meetings.

Section three includes a comprehensive analysis of the pFAST at DFW. Sufficient data was available to baseline operations before the tool was deployed as the full implementation of pFAST DFW before the FFP1 program was initiated.

The fourth section of this report focuses on the TMA. TMA has been operational at the Dallas Ft. Worth center (ZFW) since late 1996. We do not have sufficient baseline data for analysis of TMA metrics. The benefits described in this section are based on observations provided by ZFW personnel. We will have baseline data for future deployment sites, and plan to have a preliminary analysis for TMA at the Minneapolis center in the next report.

Section five provides a summary of the CDM metrics that were documented in the January 2000 report, "An Operational Assessment of Collaborative Decision Making in Air Traffic Management: *Measuring User Impacts through Performance Metrics*." For a detailed review of the CDM metrics please reference this report, which can be accessed on the FFP1 website.[2]

The sixth section provides a qualitative analysis of SMA as reported by US Airways (USA) and Northwest Airlines (NWA). SMA (Automated Radar Terminal System (ARTS) III data feed) deployment was successfully completed on time for all six planned facilities. With the installation of the proof-of-concept display, developed by Metron Inc., SMA has provided real-time information on Terminal Radar Approach Control (TRACON) activities to personnel in both airline operations centers (AOC) and ramp towers. We have several examples where SMA contributed to improved decision making and more efficient management of ground support operations.

The seventh section provides a summary of baseline data collection and analyses to date. The FFP1 Metrics Team has developed an extensive database to support the evaluation of

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[1] Based on a meeting and discussions with Toni Ferrante (AAT-20, Evaluations and Investigations) on June 7, 2000.

[2] www.faa.gov/freeflight/

operational impacts. This performance measurement database incorporates data from three primary data sources: ARTS/Host data, National Climatic Data Center (NCDC) weather data, and airport log data. This database will be updated with new facility data as the new FFP1 capabilities come on line.

This document is the first comprehensive interim report on all five FFP1 capabilities. As stated previously, the FFP1 Program Office will continue to publish similar reports on a semiannual basis. Future analyses will apply comparable methodologies at other sites as FFP1 capabilities are deployed. Additional metrics and analytical approaches may also be used to enhance our understanding of FFP1 operational impacts. We recognize the potential wide variety of readers as a result, some of the statistical analyses may warrant further discussion with the Metrics Team as appropriate.

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1.0 SAFETY

1.1 Description

The FFP1 capabilities are intended to provide benefits to users while maintaining the current high level of system safety. Maintaining a high level of safety has been a fundamental FAA objective since the agency was established, and it continues to underlie the development and implementation of every FFP1 tool. Safety objectives are reflected throughout the *Free Flight Phase 1 Program Master Plan (PMP),* the document that describes the implementation process for FFP1 capabilities. The PMP begins by defining free flight to be a system that will, among other things, "maintain the highest level of flight safety"; further, it establishes the maintenance of that level of safety to be one of FFP1's principal program objectives.

To help meet these objectives, FFP1 management has established a risk management process that will track the performance of each FFP1 tool throughout the implementation phase. The FFP1 risk management team has identified safety as one of two critical risk areas. To mitigate safety risks, service providers have been and will be involved in both the design and validation processes for all FFP1 capabilities.

FFP1 safety metrics are being used to support the FFP1 safety evaluation, thereby helping to ensure that no fielded tool will inadvertently cause a net reduction in system safety. As with all FFP1 metrics, the FFP1 safety metrics reflect collaboration with Stakeholders, and a consensus among airspace users, the FAA, industry, and unions.

In the FFP1 Metrics Plan, the principal safety metrics were defined to be the change in OEs and ODs associated with the use of the FFP1 capabilities. The plan further stated that, where possible, baseline data would be segregated by conditions or factors that influence the number of OEs and ODs (e.g., weather, traffic density, communications congestion).

1.2 Methodology

The methodology that is being used by the FFP1 Metrics Team for the analysis of OEs can be summarized as follows:

- Track facility OEs during a baseline period and after implementation of FFP1 capabilities, focusing on the total number of errors per facility and the number of errors attributed to one or more FFP1 capabilities.
- Analyze OEs data in detail during the baseline and post-implementation periods to identify and track underlying factors. Examples of such factors include
    - Traffic density
    - Controllers' timely awareness of developing conflicts
    - Communications problems
    - FFP1 capabilities in use
- In coordination with FAA headquarters, regions and facilities, establish a process to collect pertinent information relating to OEs before and after FFP1

implementation. In particular, the Metrics Team will keep appraised of the FAA Evaluations and Investigations Staff (AAT-20) program to evaluate OEs and deviations as they occur. AAT-20 will advise the Metrics Team any time an FFP1 tool is identified as a factor in any OE or OD.

- Explore the potential application of other relevant data with various FAA offices (for example, the Office of System Safety) and Stakeholders. Such data might include
    - Aviation Safety Reporting System (ASRS) data
    - Flight data recordings through the Flight Operations Quality Assurance (FOQA) program (The FOQA program is currently in its infancy, but the FFP1 Metrics Team will continue to monitor its progress.)

1.3 Preliminary Analysis Results

The FAA's Air Traffic Service Evaluations and Investigations Staff (AAT-20) has been tracking OEs and ODs at each site where an FFP1 tool has been fielded. Each OE and OD at an FFP1 site has been evaluated to see if any FFP1 tool was identified as a factor. As of 1 June 2000, no FFP1 capabilities have been identified as a factor in any OE or OD.

Monthly OE counts at the two current URET centers have been collected by AAT-20. No significant increase in monthly OE rates can be identified from these data. This occurs despite the change in the way OEs were reported after mid-1998, a change that should have increased the total number of OEs reported. (Prior to mid-1998, OEs that violated minimum separation standards by less than 0.2 miles were not counted due to assumed distance-measuring errors.) The impact of this change can be seen by noting that the number of OEs with greater than 80 percent of the minimum required separation increased by 82 percent in the last two months of 1998, and are up by nearly 50 percent in the first two quarters of FY 2000.

1.4 Next Steps

As the fielding of FFP1 capabilities proceeds, the FAA will take the following steps to continue the evaluation of FFP1's safety impact:

- Continue the analysis of OEs at current and planned FFP1 sites
- Begin a comparison between OE rates at FFP1 sites with those found at sites not hosting FFP1 capabilities
- Begin a detailed analysis of individual OE reports identifying factors that explain why OE counts vary. Possible factors include:
    - Communication problems (e.g., frequency congestion, incorrect readbacks, wrong call signs)
    - Timely controller awareness of developing conflicts.
- Explore additional data sources

2.0 USER REQUEST EVALUATION TOOL (URET)

2.1 Overview

The User Request Evaluation Tool (URET) will be implemented at five additional centers under the Free Flight Phase 1 initiative. These locations are identified in Figure 1. Currently, a URET "daily-use" (DU) system is operational at Indianapolis (ZID) and Memphis (ZME) centers.[3]

URET has been used on a daily basis at ZID and ZME since 1997. Approximately 750 operational personnel have been trained on the operation of the tool. Both facilities are operating URET 22 hours a day 7 days a week. The use of the tool at each facility has increased dramatically since 1998. Evidence indicates that controllers have come to accept the tool as a new way of doing business and have largely integrated it into their strategic planning.

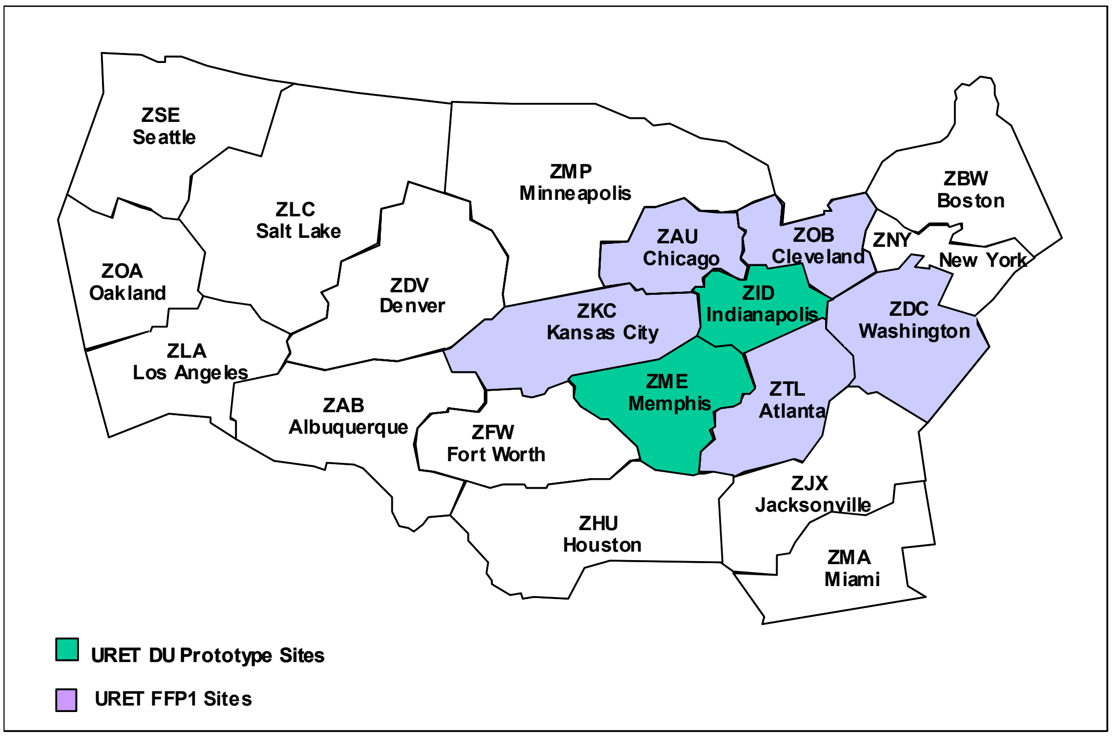

Figure 1. URET FFP1 Implementation Sites

Since February 1999, MITRE/CAASD, in conjunction with the FFP1 Program Office, has been systematically examining the use of URET at ZID and ZME on a monthly basis. Important excerpts from these reports are reviewed at each monthly FFP1 program review and in meetings with Stakeholders.

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[3] The URET DU system serves as a means of understanding procedural and training issues that need to be addressed for the success of URET in FFP1. It also provides an opportunity to evaluate prospective benefits to users and to achieve user benefits as early as possible. The URET system currently operating at ZID and ZME is the URET DU system. References to URET FFP1 refer to the Lockheed Martin URET system to be deployed during FFP1.

2.1.1 Functionality

The key URET capabilities for FFP1 are:

- Trajectory modeling;
- Aircraft and airspace conflict detection;
- Trial Planning to support conflict resolution of user or controller requests; and
- Electronic flight data management.

URET processes real-time flight plan and track data from the Host computer system. These data are combined with site adaptation, aircraft performance characteristics, and winds and temperatures from the National Weather Service in order to build four-dimensional flight profiles, or trajectories, for all flights within or inbound to the facility. URET also provides a "reconformance" function that adapts each trajectory to the observed speed, climb rate, and descent rate of the modeled flight. For each flight, incoming track data are continually monitored and compared to the trajectory in order to keep it within acceptable tolerances. Neighboring URET systems will exchange flight data, position and reconformance data, and status information in order to model accurate trajectories for all flights up to 20 minutes into the future.

URET maintains "current plan" trajectories (i.e., those that represent the current set of flight plans in the system) and uses them to continuously check for aircraft and airspace conflicts. When a conflict is detected, URET determines which sector to notify and displays an alert to that sector up to 20 minutes prior to the start of that conflict. Trial planning allows a controller to check a desired flight plan amendment for potential conflicts before a clearance is issued. The controller can then send the trial plan (TP) to the Host as a flight plan amendment. Coordination of trial plans between sectors, which might include those of neighboring centers, may be achieved non-verbally using Automated Coordination capabilities.

These capabilities are packaged behind a Computer Human Interface (CHI) that includes text and graphic information. The text-based Aircraft List and Plans Display manage the presentation of current plans, trial plans, and conflict probe results for each sector. The Graphic Plan Display (GPD) provides a graphical capability to view aircraft routes and altitudes, predicted conflicts, and trial plan results. In addition, the point-and-click interface enables quick entry and evaluation of trial plan routes, altitudes, or speed changes and the sending of flight plan amendments to the Host.

For more details about URET capabilities, benefits, and operational concept, please refer to the paper by Celio et al., 2000, on the MITRE/CAASD URET website, www.caasd.org/Research/URET.

2.2 Daily Use Metrics

In order to determine what benefits URET is providing, it is important to examine how URET is being used. Metrics on the use of various URET capabilities are collected and updated on a monthly basis. The metrics are based on the daily files generated by URET at ZID and ZME. This set of metrics has grown since February 1999 when such data were first examined on a systematic basis. The following is a subset of the May 2000 metrics that are calculated for ZID and ZME:

- URET Utilization
- Direct Routing Amendments (Counts of Total Directs and URET Directs)
- Distance Savings for Lateral Amendments

2.2.1 System Utilization

Over time, URET has grown from a single workstation to full center operations at ZID and ZME. The operational hours have grown from eight hours a day, five days a week to 22 hours a day, seven days a week. Figure 2 illustrates the usage trend over the past year. The calculation is based on the ratio of sector-hours-used to sector-hours-available. Note that scheduled hours prior to August 1999 were estimated.

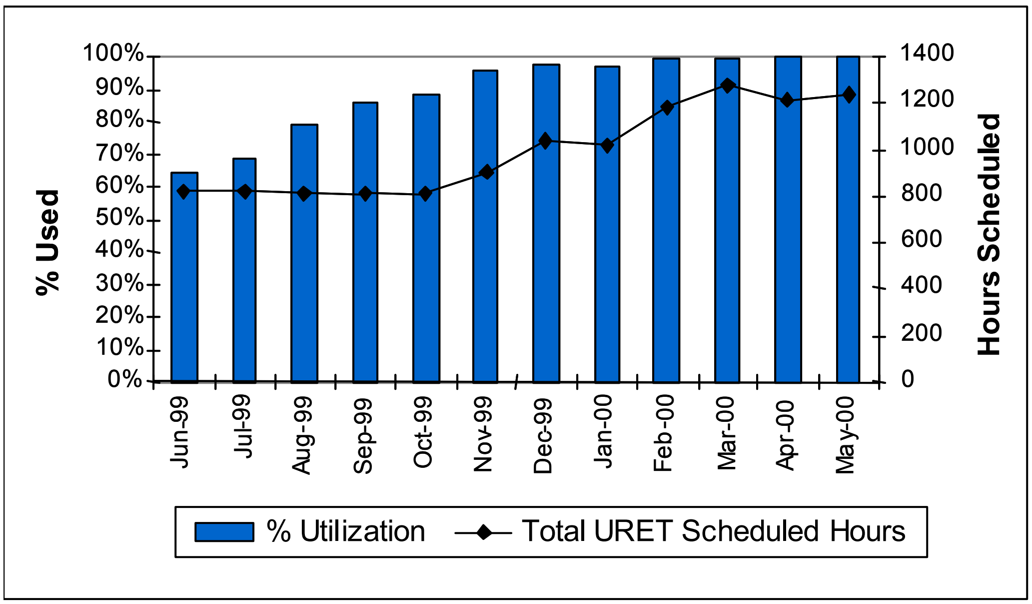

Figure 2. URET System Utilization (ZME and ZID)

2.2.2 Direct Routing Amendments

When two-way communications between URET and Host started, many URET controllers said that they were granting more directs routes (directs). This analysis looks at the number of directs in both the ZID and ZME systems and determines the source of the amendment (Host or URET).

Using the data sent to the URET from the Host, any flight plan amendment which caused a shorter trajectory to be built was considered a "direct." The URET amendments (AMs) that were created as direct TPs are also counted. The counts for ZID and ZME are shown in Figure 3 and Figure 4, respectively.

For ZID, the graph illustrates a 50 percent growth in the input of direct amendments to the Host between May 1999 and May 2000, with almost a tripling in the input of direct

AMs sent via URET since two-way began. The percentages for ZME are slightly higher although the absolute numbers are lower.

The data indicate that controllers are inputting more directs and that URET seems to be the main source of that increase.

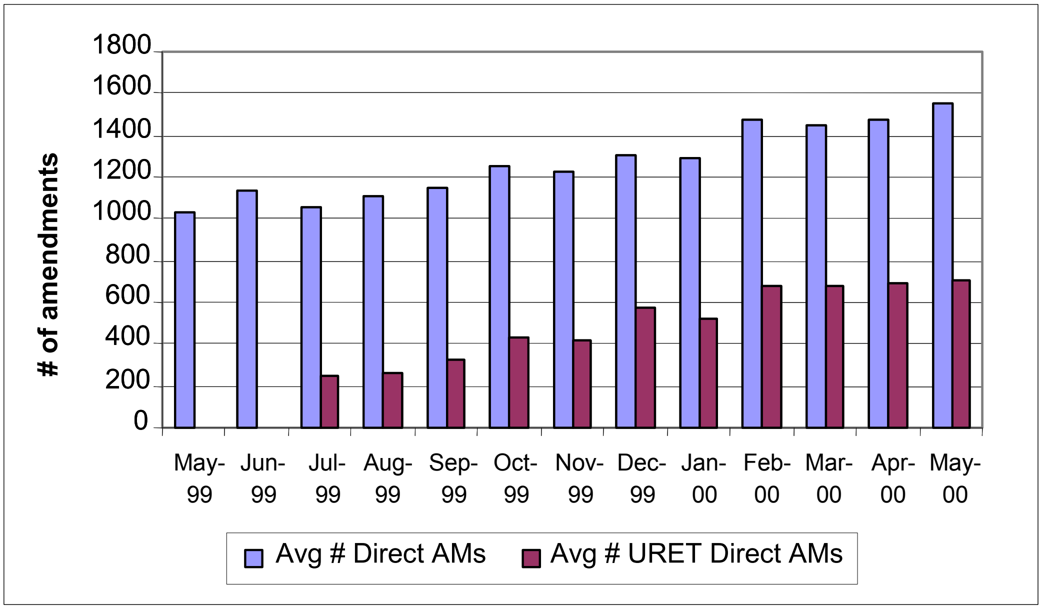

Figure 3. ZID: Counts of Total Directs and URET Directs

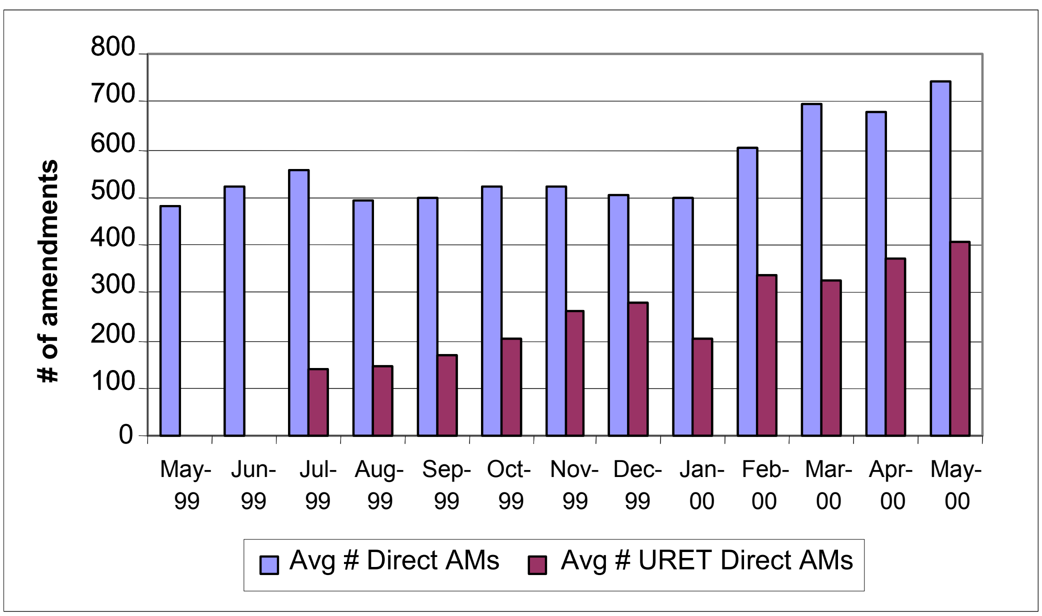

Figure 4. ZME: Counts of Total Directs and URET Directs

Note that the data were analyzed on a sampling rate of twice per week. More data reporting and analysis are needed before any firm conclusions can be drawn from this metric.

2.2.3 Distance Savings For Lateral Amendments

Using the same raw data used for the Direct Routing Amendments analysis, this metric looks at all lateral amendments (not just those with a distance reduction). The daily sum of distance saved from lateral amendments shows an overall reduction (or savings) in the lateral dimension for both ZID and ZME, as depicted in Figure 5.

Since all the numbers stay positive, ZID and ZME, overall, have been shortening routes rather than extending them. Compared to the figures in May 1999, the data indicates that both ZID and ZME have continued to increase the distance saved in granting directs.

Note that the data were analyzed on a sampling rate of twice per week. More data reporting and analysis are needed before firm conclusions can be drawn from this metric.

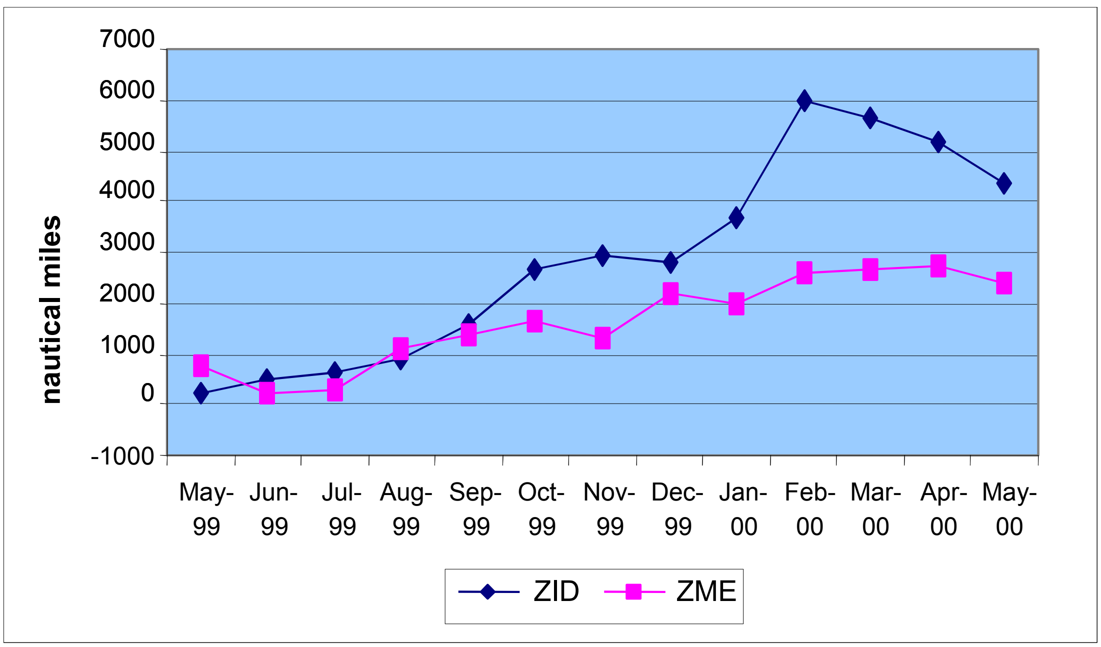

Figure 5. Distance Saved for Lateral Amendments

2.2.4 Process of Daily Use Metrics Analysis

The data for this monthly report come from tools that extract the data from the URET DU data log files: the DLOG file. The DLOGs are saved from every URET run by a site administrator and mailed to CAASD in McLean on a weekly basis. They are loaded back to local disk, and then parsed and loaded into SYBASE. From there, additional tools, reports, and SQL queries form the basis for these metrics.

2.2.5 Observed Metrics

In addition to the URET DU metrics, the FFP1 Metrics Team is evaluating metrics derivable from empirical data. These metrics may be classified as strategic-scale metrics and tactical-scale metrics. Strategic-scale metrics measure attributes of flights roughly from origin to destination, whereas tactical-scale metrics measure attributes of flights within a center. For ZID and ZME, the metrics are tabulated over a time span that begins before two-way Host deployment, with only very limited use of URET, to the widespread use experienced today. It covers the period during which controllers accustomed themselves to URET and became progressively more proficient at using it. For the URET FFP1 sites, the metrics will be tabulated over a time span that begins approximately one year before implementation to one year after the capability is in full use.

2.2.6 Strategic-Scale Metrics

Several observed metrics are classified as strategic-scale metrics. Data from the Enhanced Traffic Management System (ETMS) are used to extract the following metrics:

- En route time
- En route ground distance
- En route air distance (ETMS data in concert with Rapid Update Cycle (RUC) winds data)

En route air distance is the product of true airspeed and time, that is, the distance traveled by the aircraft relative to the air mass. This metric is used as a proxy for fuel burn. The question on all of these strategic-scale metrics is whether flights that cross the URET centers are showing improvement in these three metrics.

2.2.7 Tactical-Scale Metrics

Some of the tactical-scale metrics also use ETMS data. The ETMS data are processed to create "boundary crossing tables" which contain center traversal information (time and distance, actual and great circle) for each flight. From these "boundary crossing tables," the difference between a flight's actual distance in a center and the great circle distance is calculated. The great circle distance, used as a proxy for the shortest distance, is computed using the entry and exit point of that flight into the URET center. The question is whether gentler maneuvers within URET centers result in measurable decreases in distances.

Other tactical-scale metrics use URET DU recorded data (DLOG). From the DLOG data metrics are computed that measure the differences between a flight's actual time and distance in a center and the planned time and distance. The planned time and distance used is that time and distance according to the current flight plan when the flight enters the center. The question is whether the use of URET results in aircraft flying flight paths that are closer to what they prefer to fly.

The Host Interface Device (HID) data are used in two very different tactical-scale metrics. First, an "aggregate degrees turned" metric is computed as follows. We track the number of degrees turned by each flight, filtering out minor fluctuations in heading and filtering out corrections after turn "overshoots". We tally absolute degrees turned, so that, for example, a 25 degree turn left does not balance a 25 degree turn right (left cancels off right only when correcting for overshoots). We then normalize by calculating aggregate degrees turned per 100 nautical miles (nmi) of flight. The question is whether there are measurable signs of gentler maneuvers resulting from the use of URET to identify resolve conflicts earlier. Second, an altitude metric is computed using the HID data. For this metric, we calculate the average difference between a flight's actual altitude and the altitude contained in the flight plan that is current when the aircraft enters the center in question. This altitude is used as a proxy for the desired altitude for a portion of the flight that we identify as the cruise portion. The question is whether the use of URET results in aircraft flying nearer their desired altitudes.

2.2.8 Recent Results

We are not yet seeing meaningful patterns in most of the observed metrics. Generally, we need to collect, analyze, and plot data for more than the time period currently covered in order to observe the longer-term trend, including any seasonal cycles, before we draw more definitive conclusions.

However, an analysis of the tactical-scale metrics using HID data suggests that in both ZID and ZME, the "aggregate degrees turned per 100 nmi" metric and the "average distance below flight plan altitude" metric both decline very gently over the time span described above. The declines are on the order of 1 to 3 degrees (per 100 nmi of flight) per year, and 150 to 500 feet of altitude per year. Statistically, we find a high degree of confidence that the data represent declines (except for "degrees" in ZID, where the confidence level is above 90 percent but below 95 percent). However, we must note that *statistical* significance may not translate into an *operationally* significant result, and as pointed out above, more time and data are needed before we draw more definitive conclusions.

2.3 Ongoing URET Benefits Work at ZID and ZME

Controllers at ZID and ZME are continuing to use the URET DU system to provide benefits to National Airspace System (NAS) users. They have taken an active role in the area of relaxing static altitude restrictions.

The methodology for analyzing the removal of restrictions has three major aspects: data analysis, operational evaluations, and airline participation. The data analysis work consists of using internal CAASD tools to help identify candidates for relaxation before a restriction is lifted, and determining the NAS-user benefit from the lifting of the restriction.

As described in the next section, operational evaluations at ZID and ZME are continuing and expanding. Airline involvement and participation continues to increase and become more directed and effective.

The following section describes the work of the Procedures and Benefits Teams at ZID and ZME in the lifting of restrictions, specifically in identifying candidates for removal. Also described is an example of a restriction relaxation activity undertaken at ZID with arrivals into Pittsburgh. The final section describes the airline involvement and participation in the Teams.

2.3.1 Restriction Relaxation Activities of the Procedures and Benefits Teams

Procedures and Benefits Teams were formed at the two sites in the autumn and winter of 1999 to review operations and determine how URET can help in strategic planning. The teams are reviewing static altitude restrictions to identify candidate restrictions that can be relaxed.

Table 1. History of Restriction Relaxation at ZID and ZME

DATE	ZID or ZME	RESTRICTIONS		IMPACT Potential Savings			
		Restriction	Evaluation Hours or Days	No. of Aircraft	Average NMI per a/c*	Average Gallons per a/c*	Reinstated Yes or No
5/27/99	Both	Nashville (BNA) arrivals; from ZID to ZME sector 41 at FL200 or below	2 hrs.	9	38.7	15	Yes
12/29/99	ZID	Indianapolis (IND) arrivals, from sector 84 to 82 at FL310 or below	3 ½ hrs.	4	59	11	Yes
12/30/99	ZID	BNA arrivals; from sector 80 to 81 at FL290 or below	2 hrs.	1	73	20.4	Yes
2/24 - 2/25/00	ZID	IND arrivals from sector 87 to 88 at FL310 or below	4 hrs.	18	57	8	Yes
2/25/00	ZID	Columbus arrivals (A.73) from sector 85 to 86 at FL290 or below	4 hrs.	10	54	7	Yes
3/13 - 4/12/00	ZME	All BNA arrivals 5 Restrictions	30 days**	28	0	0	No
4/1 - 4/14/00	ZID	IND arrivals from sector 18 to 34 at 15,000 feet or below	14 days**	9	9.1	.53***	Yes
4/1 - 4/14/00	ZID	Louisville arrivals from sector 35 to 17 at 15,000 feet or below	14 days**	2	18.5	3.78***	Yes (temporarily)
5/21/00	ZID	Pittsburgh arrivals from sector 83 to 85 at FL290 or below	Permanent	9	88.5	25***	No

* For time of analysis
** 24 hours a day
*** Estimated, based on B737-800

The impetus for the establishment of the Teams was an inter-facility evaluation of restriction relaxation between ZID and ZME that took place in May 1999. Specific restrictions for arrivals into Nashville (BNA) from ZID airspace and into Louisville/Standiford (SDF) from Memphis airspace were lifted for a two-hour period (for details see Ricker et al., 1999). There was general agreement at ZID and ZME that the URET capabilities did support the restriction relaxation and that URET assisted controllers with conflict prediction. Operational personnel acknowledged that URET worked well as an enabler in this short evaluation. They expressed a willingness to review other restrictions and lift them as appropriate. The establishment of the Procedures and Benefits Teams was the result.

The Teams meet once a month. They consist of one controller from each area, a traffic management specialist, and airspace and procedures specialist, a training specialist and two supervisors. The history of the restriction relaxation evaluations at both ZID and ZME, from the initial evaluation in May 1999 through current activities, is documented in Table 1.

2.3.2 Evaluation of Restriction Relaxation at ZID and ZME

It is apparent from a review of Table 1 that the Procedures and Benefits Teams at ZID and ZME have become progressively more aggressive in their willingness to lift restrictions and evaluate the results. During calendar year 1999, three restrictions were temporarily lifted and then reimposed (described in Walker, Lowry, 2000). So far, during calendar year 2000, six sets of restrictions have been evaluated. Of these, arrival restrictions into BNA in ZME airspace have been permanently lifted. An arrival restriction into Pittsburgh was permanently lifted on 21 May 2000.

In each instance, the URET Procedures and Benefit Team identified restrictions that were candidates for removal. During the evaluation period, the restrictions were turned off in URET and the controllers did not issue the restrictions to the aircraft. However, the Team monitored the process to determine if the situation was acceptable, or if conditions required that the restrictions be reimposed early. At the conclusion of the test period, the effects were assessed to determine whether or not to permanently remove the restrictions.

The next section provides an example of one restriction relaxation activity undertaken by ZID this year. Other restriction relaxation activities have been performed but will not be discussed in this report.

Unless otherwise noted, fuel savings specified in the following sections are based upon actual calculations of aircraft types and length of time that aircraft were required to stay at the restricted altitude. Fuel burn data by altitude for 727s, 737s, 757s, 767s, Canadair Regional Jets (RJs), and MD80s was provided by the airlines. Fuel burn calculations for other aircraft types are estimated.

2.3.3 ZID Example: Pittsburgh Arrivals

The ZID Procedures and Benefits Team decided at their May meeting to permanently remove the arrival restriction into Pittsburgh from sector 83 to sector 85, which constrained aircraft to an altitude of FL290 or below. The action became effective on 21 May 2000. The crossing boundary is approximately 210 miles from the airport (see

Figure 6). This action was not a direct result of any URET test. This crossing was to be evaluated in June. However, prior to the planned evaluation, controllers and supervisors involved stated that since they have URET probing the airspace, they do not need to "miss airspace" (i.e., keep the Pittsburgh arrivals below other traffic in order to separate streams of traffic from each other). According to site personnel, the workforce realized how effective URET is in this type of situation, and decided to permanently remove the restriction.

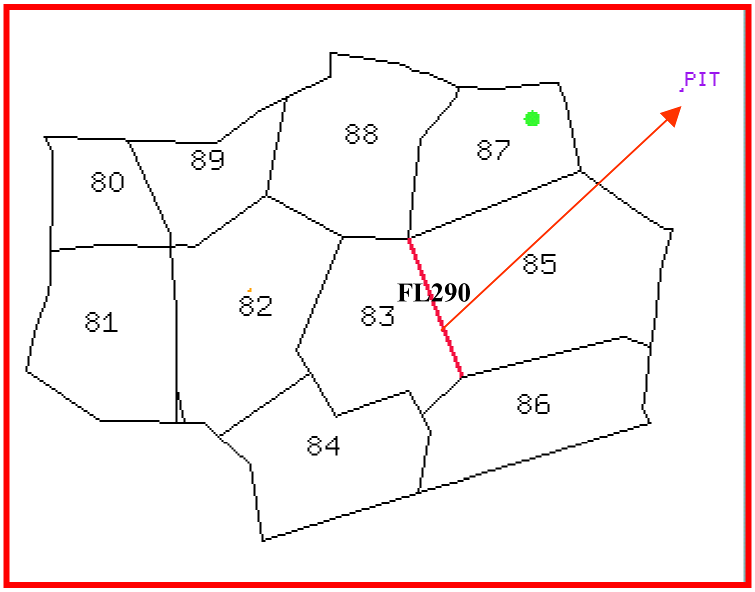

Figure 6. Indianapolis Altitude Restriction Removal: May 2000

A run of the Analysis and Restriction Tool (ART) on April 6, 2000 indicated that 9 aircraft crossed from sector 83 to 85 and would have stayed at altitude an average of 88.5 nmi longer. The fuel penalty was estimated at 25 gallons per aircraft, based on the fuel burn rate of a 737-800. The total savings, if they had stayed at altitude the extra 88.5 nmi, would have been 225 gallons of fuel.[4]

Assuming that the traffic was representative on April 6, 2000, the lifting of this one restriction would save about 82,125 gallons of fuel annually.

2.3.4 Airline Participation

The ZID Procedures and Benefits Team invited airline participation in their meetings on a regular basis. The first meeting was held in January of this year; the second meeting was held in April. Meetings will be held on a quarterly basis. The purpose of these meetings is to:

- Provide airlines with a better appreciation of traffic management requirements
- Acquaint the carriers with the capabilities of the URET system as an enabler for operational personnel to provide benefits to NAS users
- Provide operational personnel with a better understanding of airline requirements

[4] These results have been validated by US Airways analyses.

- Enlist the support of airlines in quantifying the benefits work that ZID operational personnel have undertaken

The two meetings to date have been very successful. At the first meeting, eight airlines were represented: Delta, Northwest, Comair, Southwest, US Airways, United, United Parcel Service, and Ryan International. Airline personnel were given a tour of the control room in order to observe URET in use by control personnel. It was their first exposure to URET. Each member of the URET team presented a brief overview of his area, in order for airline personnel to better understand the traffic flows. Team members also explained how URET is utilized in different situations to aid the controller in the decision making process. They also explained how much easier URET has made the job of managing the manual control position.

At the second meeting in April, all of the above airlines except Southwest sent representatives. Members of the ZID Procedures and Benefits Team and FFP1 Program Office asked the airline representatives which restrictions were most burdensome to them in order to identify which restrictions most impede traffic, from an airline perspective. For each new URET site, the FFP1 Program Office is planning to compile a list one year before URET FFP1 is deployed. They also would like to know which restrictions the airlines find most onerous.

The collaboration of ZID operational personnel and airline representatives is very promising. Both groups are developing a better understanding of each other's problems. The airlines are getting an understanding of how the strategic capabilities of URET help controllers manage traffic. The two groups are working toward a common goal of increasing benefits to users of the NAS while maintaining safety.

2.4 Fuel Burn Analysis

Determining the economic impact of removing static altitude restrictions on the airlines requires the knowledge of the miles gained en route at more efficient altitudes, the type of aircraft affected, and the fuel burn differential for the altitudes involved. This data can then be combined and extrapolated to yield an estimate of the gallons per year of jet fuel saved, which can be converted to dollar savings with an estimate of the average dollar per gallon fuel cost.

With the availability of this information, valuation of the reported benefits from altitude restrictions can take place. For example, using this methodology in the previous example, US Airways estimated a savings of approximately $125,000 annually through the removal of an arrival restriction into Pittsburgh.

2.4.1 Determination of Flights Affected by a Particular Restriction

The primary tool used to analyze the number of flights subject to each restriction is the ART tool built at CAASD. The ART tool provides data on which restrictions impact traffic the most.

For a given sample set, ART determines how many aircraft are eligible for a given set of restrictions, how long the aircraft stay at the restricted altitude, and other statistics. Using this information, the ART output can be used to determine which restrictions have the most impact on ATC and airline operations.

2.4.2 Calculation of Penalties Incurred Due to the Restriction

Restrictions were selected from the complete set of ZID restrictions for a detailed analysis. The selection criteria used were the number of aircraft affected by the restriction and the severity of the impact of the restriction on the effected aircraft. Originally, six restrictions were chosen; this was eventually expanded into nine restrictions under study. Table 2 contains the results of an ART run made on 20 hours of ZID data for 26 May 1999. The significant data in this table is for each restriction selected; the table gives the number of aircraft affected by the restriction, and the average number of miles the aircraft remained at the restriction altitude. This distance is a measure of the distance at which the aircraft flew at a lower, less efficient altitude, because of the restriction.

Table 2. Impact of ZID Restrictions Analyzed

Restriction Number	Type	Restriction	Number of Flights	Average Path Length
A.26	A	CVG_A_81/82_240	83	21.1
A.17.1	A	CVG_A_87/23_VIA_BOWRR_240	79	20.4
A.21	A	CVG_J_35/34_170	74	21.8
A.23	A	CVG_A_84/83_VIA_DRESR_240	64	28.6
A.25	A	CVG_A_80/35_VIA_JEANE_240	58	25.8
A.24	A	CVG_A_85/83_VIA_50_W_HNN_240	44	5
A.01	A	BNA_A_80/81_290	4	80.9
A.37	A	IND_A_87/88_310	6	13.9
A.36	A	IND_A_84/82_310	10	45.6

To determine the fuel penalty incurred due to the restrictions the distribution of aircraft types and the fuel burn at different altitudes for each aircraft type is required. Table 3 is the distribution of aircraft types for the original six restrictions studied. The aircraft type most often affected was the Canadair Regional Jet (CARJ). This occurs because Cincinnati (CVG) is a hub for Comair, which is a regional airline using CARJs. Airlines provided a limited amount of data concerning the fuel burn of the CARJs. They also provided fuel burn at various altitudes for Boeing 727,737-800,737-300,757,767 and MD88s. This data was normalized to the fuel penalty per mile compared to fuel burn at FL350 and plotted. Figure 7 is the combined plot of the fuel penalties in pounds of fuel per nmi flown at the less efficient altitude. Note that the CARJ normally does not operate above FL290, therefore its penalty goes to zero at FL290.

The data in this figure can be used two ways to evaluate the impact of a restriction on a particular flight. If the desired flight level (FL) for that flight is known, subtract the penalty for the desired FL from the penalty for the restriction FL. This is the net penalty for imposing that restriction on that flight. If the desired FL is not known, use the penalty for the FL of the restriction directly. This will give an upper bound on the penalty incurred from invoking the restriction. For example, for a Boeing 737-300 the fuel penalty for FL310 compared to FL350 is 1.2 pound per nmi, and the penalty for FL 240 is 2.6 pounds per nmi. A flight that has filed for FL310 that is subject to restriction A.26 (see Table 2) will fly 21.1 miles at the less efficient altitude. The penalty is the difference of the penalties for each FL (2.6-1.2) times the miles flown; (i.e., 1.4*21.1) for a total penalty of 29.5 pounds of fuel.

The data from Table 2 for the average path length flown at the restriction altitude, combined with the distribution of the aircraft affected and fuel burn at the restriction altitude for each aircraft is the basis for the estimate of the fuel penalty incurred for each restriction for one day. Note that there were only distributions available for the first six restrictions. It was assumed the distributions for the other three restrictions were similar. Assuming this is a representative day, these daily penalties can be multiplied by 365 to estimate the yearly penalty. Table 4 contains the result of that calculation in pounds and gallons.

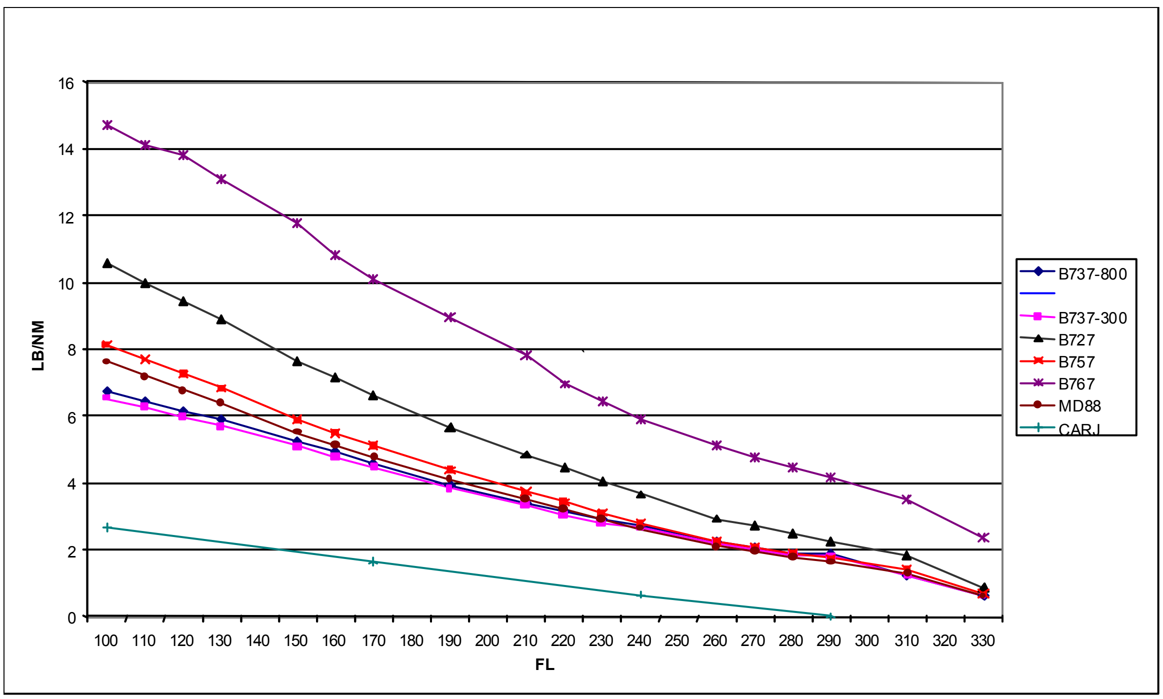

Figure 7. Fuel Penalty Reference to FL350

Table 3. Aircraft Distribution

	737	757	767	727	MD80	CAR J	E145	Lears	L1011	MD11	MD90	Others	Total
A.26	7	6	2	9	14	32	2	2			1	8	83
A.17.1	5	8	3	6	15	41	1	0				0	79
A.21	6	2	1	11	10	34	4	0	1	1		8	78
A.23	1	8	2	4	14	31	0	1	1			2	64
A.25	3	1	1	8	7	32	0	0	1	1		4	58
A.24	6	5	1	6	6	16	1	0	0			3	44
Total	**28**	**30**	**10**	**44**	**66**	**186**	**8**	**3**	**3**	**2**	**1**	**25**	**406**

Table 4. Fuel Penalty per Restriction

Restriction Number	LB/Day	LB/Year	Gal/Year
A.26	3861	1336441	199469
A.17.1	2948	1075947	160589
A.21	5830	2128020	317615
A.23	3416	1246939	186110
A.25	2621	956767	142801
A.24	476	173795	25940
A.01	557	203156	30322
A.37	84	30695	4581
A.36	669	244334	36468
Total	20263	7396094	1103895

2.5 Next Steps

This section describes some future work that the FFP1 Program Office plans to undertake to expand URET user benefits. It also addresses the work that the FFP1 Office, with the assistance of CAASD, is doing to formalize the methodology that is evolving at ZID and ZME to provide benefits to NAS users. The plan is to transfer this methodology to the other URET FFP1 sites.

2.5.1 Future Benefits Work

The expansion of URET to seven contiguous sites provides opportunities for more extensive benefits analyses. The work to date has focused on relaxation of static altitude restrictions. In addition to altitude restrictions, there are preferred routes that are flown between city pairs and through large blocks of airspace that do not correspond to any single facility boundary. Some of these routes can be circuitous causing additional flying time and distance. The FFP1 Program Office will analyze these routes to determine if more direct routings can be granted with URET FFP1 in operation.

Another future area for investigation concerns the relationship among the routes airlines would prefer that their aircraft fly, the routes that airlines actually file, and the routes that the aircraft end up flying. A still unanswered question for future investigation is whether airlines file flight plans that reflect what they would like to fly. Do the flight plans reflect the routes desired by the airlines or the routes that the airline dispatcher considers the best route given the known constraints (or preferred route established by FAA)? And how often is the filed route actually flown without a flight getting rerouted?

2.5.2 Expansion of Benefits Work

During the 2001-2002 timeframe, FFP1 URET will be deployed at the seven sites. By the time the new sites approach operational usage, a plan for evaluating restrictions for relaxation and possible removal within those facilities will already be in place.

The methodology under development includes:

- Working with operational personnel to identify and evaluate restrictions and to optimize the use of URET
- Working with the airlines to determine what restrictions it would most benefit them to relax
- Performing the data analysis to help identify restrictions for evaluation (before the fact) and to analyze the impact of restriction relaxation (after the fact).

2.5.3 Coordination with Operational Personnel

The FFP1 Program Office is working with operational personnel at ZID and ZME to develop a set of URET recommended operational 'practices' in the use of URET. The goal is to maximize benefits and increase the operational utility of URET. The recommended operational practices will be used in the development of the training program for the future FFP1 URET sites.

The Metrics Team will continue to work with the Procedures and Benefits Teams as their processes evolve and they learn more about the necessary conditions for lifting restrictions. The Teams are currently lifting some intra-facility restrictions and evaluating the results. Their work will expand to address inter-facility restrictions between ZID and ZME (the two URET sites), and, possibly, outbound restrictions to non-URET centers. The experience gained and "lessons learned" by the Procedures and Benefits Teams will be factored into the development of the methodology for benefits achievements at the new URET sites.

One year before deployment, the Metrics Team is planning to review airspace altitude restrictions at the new FFP1 URET sites to determine which restrictions have the greatest impact on flights and which of these each facility thinks can be removed.

2.5.4 Coordination with Airlines

The Metrics Team will continue the ongoing dialogue with the airlines. The airlines now meet quarterly with the ZID Procedures and Benefits Team. At the last NAS Users Day meeting in April 2000, members of the FFP1 Metrics Team asked the airline representatives for a list of restrictions at all seven FFP1 URET sites that most impede traffic from an airline perspective. The Program Office intends to consider the airline input in conjunction with the list of restrictions that the sites develop to identify restrictions for future testing and possible removal.

The airlines are the biggest benefactors of the ongoing restriction relaxation work. They have been very helpful in quantifying the benefits by providing the FFP1 Metrics Team with fuel burn data by aircraft type at various altitudes. FFP1 personnel will continue to work with the airlines to enlist their support in future efforts to quantify savings in time, distance and fuel burn.

2.5.5 Data Analysis

The ongoing FFP1 URET metrics and benefits work will continue at both ZID and ZME. The monthly data analysis and reports have expanded to provide more information on the benefits for NAS users. CAASD has recently added the following reports to its standard monthly output:

- Savings from Directs: Savings in distance that aircraft travel resulting from the controller clearing aircraft direct via URET to downstream fixes
- Lateral Distance Saved: Distance saved from all lateral amendments (including directs as well as penalties), the average of the daily sum of nautical miles changed

Using the ART tool, CAASD will continue to provide input on candidates for restriction relaxation and will also continue to evaluate the benefits resulting from lifting specific restrictions. Two additional sets of tools are also being developed which include:

- Trajectory analysis tools that analyze the change in the trajectory due to the restriction, as if the aircraft were the only aircraft in the sky. The changes examined in the trajectory include change in time of arrival, distance between top of descent (TOD) points with/without arrival restriction, distance between top of climb (TOC) points with/without departure restriction, and difference in altitude between filed altitude and restriction altitude.
- System impact tools that look at the impact on the center when a restriction is lifted. These tools include before and after restriction(s) removal checks on sector density and conflict count. Sector density is measured by counting aircraft volume in a sector. The center conflict counts look at the change in the number of conflicts found by the conflict probe at the aggregate center level to determine if conflict count changes significantly due to restriction removal.

3.0 PASSIVE FINAL APPROACH SPACING TOOL (pFAST)

3.1 Description

The Passive Final Approach Spacing Tool (pFAST) is used by controllers and air traffic managers to manage the flow of arrivals in terminal airspace. pFAST computes a runway assignment and a relative sequence for arrival aircraft for each runway at a particular airport in such a way as to minimize overall flight delay, with consideration given to aircraft type, speed, and trajectory. These advisories are displayed to the controller on the ARTS display. The controller may manually override both the relative sequence number and the runway advisory displayed by pFAST, and the system automatically adjusts to sequence number changes.

3.2 Overview of pFAST Implementation

pFAST became operational at the DFW TRACON in early 1999, but use was originally limited to a subset of controllers referred to as the Cadre. In the first two weeks of operational use with the airport in a south flow configuration, pFAST was used for over 80 percent of the arrival rushes. The National Aeronautics and Space Administration (NASA) data indicates controller acceptance of the runway advisories was 96.9 percent during this two-week period, and acceptance of the sequence advisories was also high.[5] During the months of February through June 1999, pFAST was used by the Cadre 71 percent of the time that the airport was on a south flow. By the end of the year pFAST was used nearly 100 percent of the time the airport was on a south flow, and the entire staff was using the system. By the spring of 2000, the facility was using pFAST when the airport was on a north flow.

3.3 DFW Management Initiative

In July 1999 the DFW TRACON began a new traffic flow management regime, which significantly impacted operations. The TRACON Traffic Management Unit (TMU) began intensifying the use of parallel (or dual) arrival routes to allow higher flow rates into the TRACON at peak times. Traffic managers indicated that this new regime was adopted in order to "load up" pFAST. Nevertheless, the dual routes have been in use during peak arrival periods since July 1999 regardless of the status ("on" versus "off") of the pFAST system.

Figure 8 illustrates DFW terminal airspace and the dual arrival fixes. The dual arrival fixes are used when a particular corner post is experiencing heavy arrival demand. The TMU will open an additional fix so that another arrival stream is created, in addition to the two streams that are brought in altitude-separated over the primary arrival fix. As an example of this procedure, when arrival traffic is heavy over the northeast corner post, the TRACON TMU will open the SASIE fix for an additional flow of arriving aircraft.

[5] National Aeronautics and Space Administration (NASA) Ames website http://www.ctas.arc.nasa.gov/.

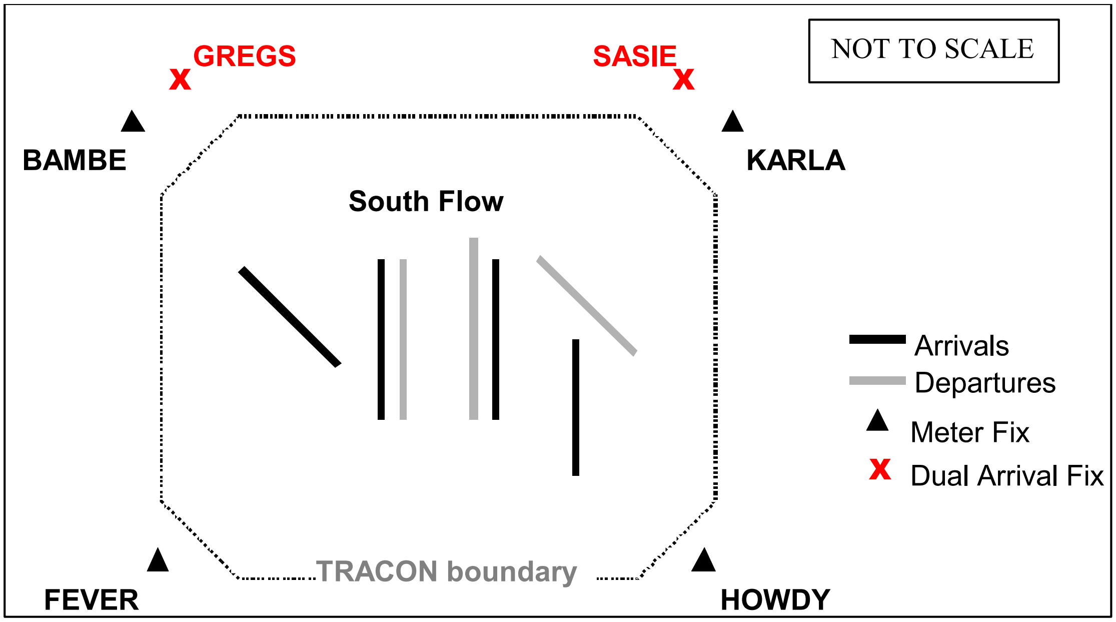

Figure 8. Dual Arrival Routes into DFW TRACON Airspace

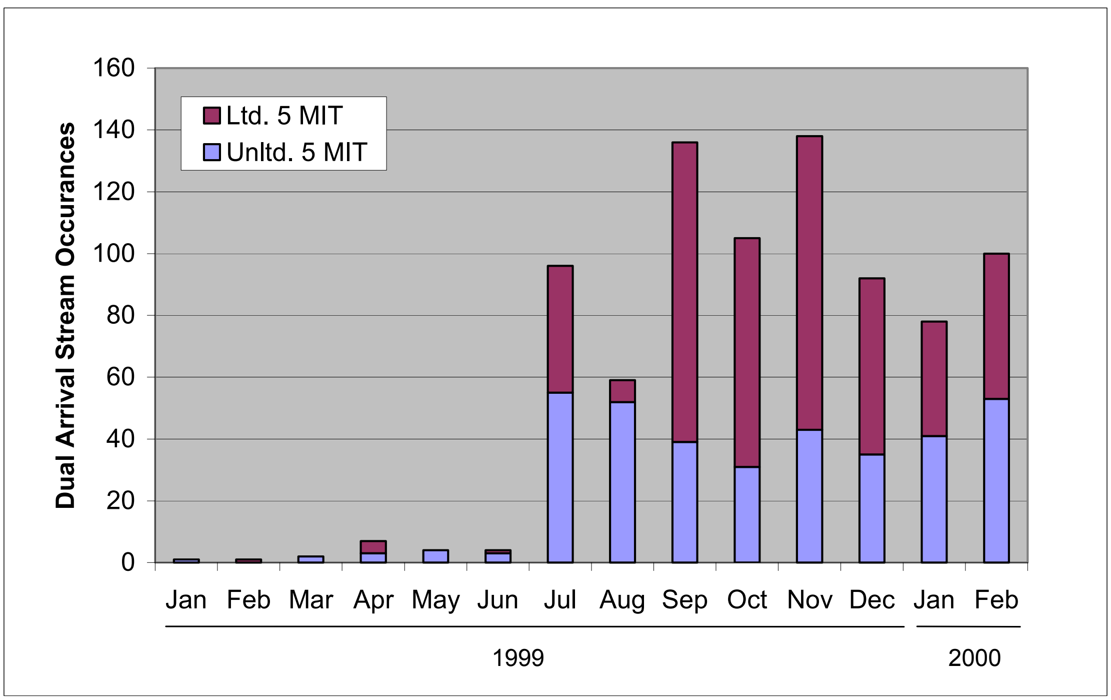

Figure 9. DFW TRACON Usage of Dual Arrival Routes (Jan. 1999 – Feb. 2000)

Figure 9 plots the usage of five Miles-in-Trail (MIT) dual arrival routes at DFW TRACON over time. Dual routes at DFW are categorized as either "limited" or "unlimited," as well as by the MIT specified for aircraft on the route. When specifying a limited dual route, the TRACON TMU will tell Ft. Worth center exactly how many aircraft they would like delivered on the route. When an unlimited dual route is opened, the center may deliver as many aircraft over the route as they like, as long as the MIT limit is not violated and the overall acceptance rate is adhered to. As Figure 9 illustrates, the use of both limited and unlimited 5 MIT dual routes increased significantly in July 1999.

An additional change in DFW TRACON operations was observed on or around July 1, 1999. American Airlines (AAL), the dominant airline serving DFW, issued schedule changes that affected block times for flights destined for DFW. This change resulted in approximately two additional arrival aircraft being scheduled into the peak arrival periods. This change affects the demand available for pFAST service. The analyses presented later in this section revealed higher throughput during peak periods, and therefore support the belief that pFAST contributed to the servicing of additional demand. In interviews with the FFP1 Metrics Team, AAL personnel reported that this schedule change was not motivated by the implementation of pFAST.

3.4 Daily Use Metrics

The pFAST usage data (in 10-minute intervals) has been collected at the DFW TRACON since pFAST was first deployed. Figure 10 presents the hours available versus hours used for pFAST on South Flow at DFW. The FFP1 Metrics Team used this data to test for the significance of the automation's effect on several customer-driven performance metrics: arrival rates, ground movement times and flying times, runway balancing, and throughput rates (arrivals plus departures).[6]

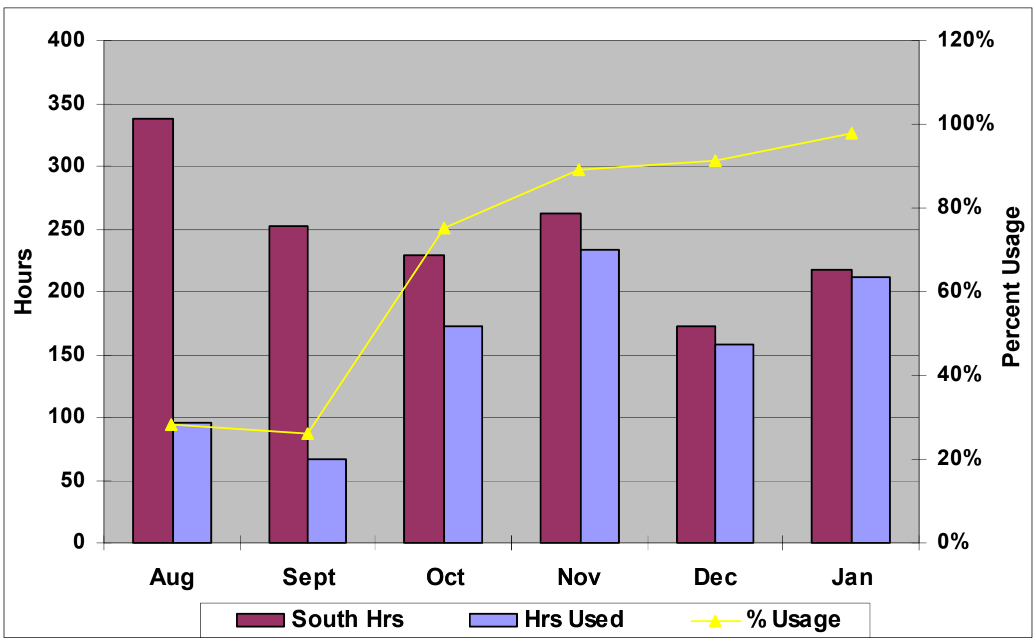

Figure 10. pFAST Usage on South Flow (hours and percentage)

[6] Federal Aviation Administration, *Free Flight Phase 1 Performance Metrics: An Operational Impact Evaluation Plan, Version 1.0*, August 12, 1999.

3.5 Operational Impacts at DFW

Five metrics relating to the operational impact of pFAST at DFW have been studied over the past six months and are discussed in detail below: the DFW Airport Acceptance Rate (AAR), peak *actual* arrival rate, airport throughput (arrivals plus departures), TRACON flight time (i.e., average time of flight from the meter fix to the runway threshold), runway balance, and taxi time.

3.6 Analysis of Airport Acceptance Rate

We have observed from TRACON logs that over the past year AARs at DFW have on average increased, and that the maximum AAR being recorded has also increased. In order to determine quantitatively if pFAST usage has led to this observed increase in AARs, we performed a regression analysis of the airport acceptance rate and various environmental variables that, in the judgment of experienced air traffic controllers, should affect the AAR. Specifically, we regressed the number of arrival runways in use, the type of approaches being used (visual or instrument), the natural logarithm of cloud ceiling, the square of the surface crosswind component, and a pFAST dummy variable on AAR.[7]

We also included a dummy variable that accounts for the before mentioned (see Section 3.3, DFW Management Initiative) traffic management initiative implemented in July 1999. We included data in ten-minute increments from February 20 through December 31, 1999, for a total of approximately 220,000 observations.

The results of this regression analysis are presented in Table 5. All of the variables included in this model were found to be significant at the five percent level, and the signs of the coefficients were what we would expect. For example, when DFW uses three arrival runways (rather than four), the acceptance rate is reduced by approximately 22 aircraft per hour, all else being equal. Similarly, when the ceiling increases by one decade from 100 to 1,000 feet, the acceptance rate increases by 0.97 ln (1,000 - 100) ≈ 6.6 aircraft per hour. After controlling for all of these factors, we found that pFAST usage resulted in an increase in acceptance rates of approximately 2.5 aircraft per hour.

[7] In actuality, we used the Airport Landing Rate (ALR) for this analysis. The ALR adds to the AAR an additional arrival traffic count, and is a more accurate representation of the total arrival rate being specified for the airport. The DFW TRACON is the only approach control facility in the United States that makes such a distinction.

Table 5. DFW Acceptance Rate Regression Analysis

Dependent Variable:	
AAR	Airport Acceptance Rate (arrivals/hr)
Independent Variables:	
3_Runways	0 - four arrival runways 1 - three arrival runways
IFR	0 - visual approaches 1 - instrument approaches
UnltdDuals	0 - FEB 20 - JUN 30 1999 1 - JUL 1 - DEC 31 1999
Ln_Ceiling	natural logarithm of ceiling in feet
NorthFlow	0 - south flow 1 - north flow
CrosswindCompSq	square of crosswind component in knots
pFAST	0 - pFAST off 1 - pFAST on

	Unstandardized Coefficients		Standardized Coefficients		
Independent Variables	B	Std. Error	Beta	t	Sig.
(Constant)	127.936	.173		739.002	.000
3_Runways	-21.871	.060	-.444	-366.191	.000
IFR	-13.978	.038	-.540	-368.845	.000
UnltdDuals	1.382	.030	.058	45.793	.000
Ln_Ceiling	.970	.017	.085	58.499	.000
NorthFlow	-.936	.031	-.036	-29.775	.000
CrosswindCompSq	-.01196	.000	-.049	-40.816	.000
pFAST	2.486	.030	.098	82.543	.000

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.859	.739	.739	6.0243

3.7 Analysis of Increased Arrivals

The number of arrivals during peak arrival periods into DFW was examined. The study was based on February 1999 through February 2000 data. The data used in this study were derived from DFW TRACON Traffic Management logs. The number of arrivals was reported in 10-minute intervals from 0600-2350, local time. This data was then processed to capture the 8 busiest 30-minute periods each day. The data was segregated into instrument and visual arrival conditions. The study examined only those observations during times where four arrival runways were in use at DFW. Figure 11 suggests that there has been an increase in the average peak arrival rates at DFW during pFAST usage. The numbers displayed at the bottom of each of the columns in the chart indicate the size of the population. A t-test of means indicates that the differences are statistically significant at the five percent level. [8]

[8] Broadly speaking, a t-test of significance is a procedure by which sample results are used to verify the truth or falsity of a hypothesis test.

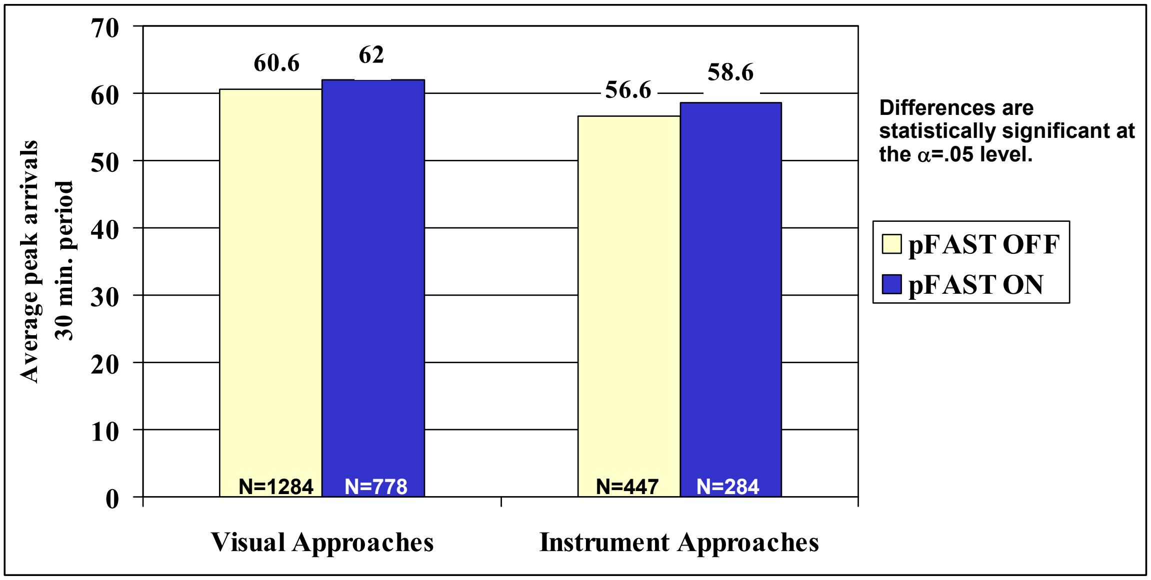

Figure 11. Increased Arrivals During Peak Periods

3.8 Analysis of DFW Airport Operations (Arrivals and Departures)

The number of operations, including arrivals and departures, during peak arrival periods into DFW was also examined. The study was based on April 1999 through February 2000 data. Again, the number of operations was reported in 10-minute intervals from 0600-2350 local time. This data was then processed to capture the 8 busiest 30-minute periods each day. The data was segregated into instrument and visual arrival conditions. The study examined only those observations during times where four (4) arrival runways were in use at DFW. A t-test of means indicates that the differences are statistically significant at the five percent level.

Figure 12 suggests that there has been an increase in the mean peak operations at DFW during pFAST usage. In discussions with facility personnel we have learned that when the number of arrivals to each runway are better balanced departure aircraft are delayed less. This is due in part to less need for arrival aircraft to taxi across active departure runways.

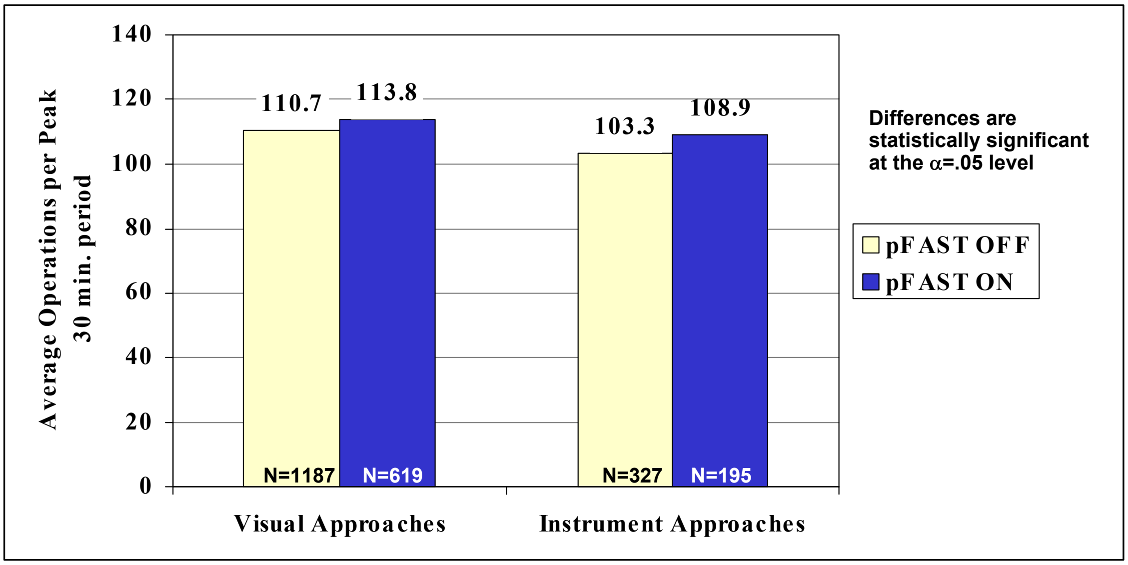

Figure 12. Increased Operations (Arrivals and Departures) During Peak Periods

3.9 Analysis of TRACON Arrival Flight Times

In order to ensure that the increases in airport arrival rates and throughput reported above were not obtained at the cost of increased flight delays, we analyzed arrival aircraft flight times in the DFW TRACON, both when pFAST was in use and when the tool was not in use. The NASA field station at the Ft. Worth center (ZFW) provided flight time data by extracting from log files produced by TMA at ZFW. Average flight times from the meter fix to the runway threshold were computed for 199,391 arriving flights between 19 January and 31 December 1999. Only flights arriving when the airport was in a south flow configuration and utilizing four arrival runways were selected for this analysis. Mean TRACON flight times are presented in Figure 13. Only small differences in flight times were evident under either visual or instrument arrival conditions. These differences are not statistically significant at the five percent level. We may therefore conclude that there has been no appreciable change in flight times within the TRACON as a result of pFAST implementation and usage.

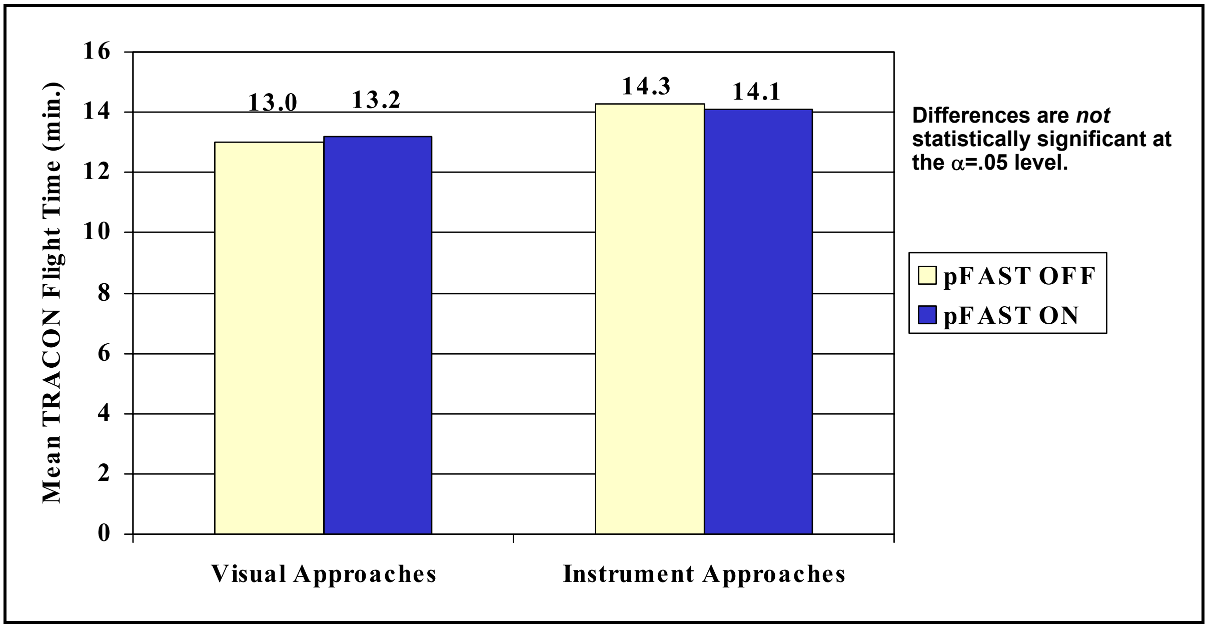

Figure 13. DFW TRACON Flight Times

3.10 Analysis of Ground Movement Times

As part of the FFP1 Metrics Team's analysis of the impact of pFAST at DFW, data on taxi times at DFW are being collected to evaluate changes with and without pFAST. The data is being drawn from the FAA's Consolidated Operations and Delay Analysis System (CODAS); the period of analysis is currently August 1999 through April 2000.

Hourly average taxi-out and taxi-in times have been drawn from the CODAS database during the period of analysis. Taxi times for the "pFAST in use" periods were then identified based on information from the DFW TRACON Daily Record of Facility Operations. If the daily logs indicated that pFAST was used for more than half the day, then we considered the system to have been used for the entire day.

To date, the analysis shows a slight increase in taxi-in times and a somewhat larger decrease in taxi-out times when pFAST is in use. Neither difference is statistically significant at the five percent level. The results are shown in Figure 14.

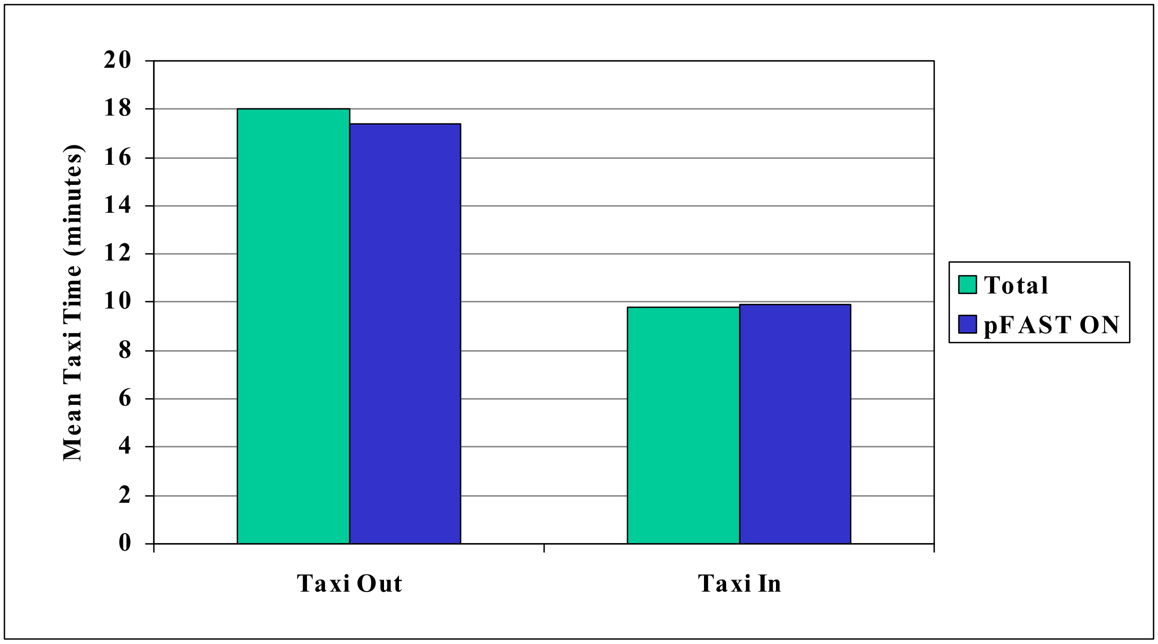

Figure 14. pFAST Taxi Time Analysis at DFW, Aug. '99 – Apr. '00

3.11 Analysis of Improved Runway Balancing

Another performance metric that was examined was the "balancing" of the runways. Runways are considered to be balanced if the arrival rates on the individual runways are approximately equal. By balancing the runways, the overall arrival rates may be increased and surface congestion reduced. Our relatively simple measure of the degree to which the arrival runways are balanced is the difference in the percent of arrivals handled by the most used and least used arrival runways.

The data used for this calculation are the same used in the above analysis, namely the 10-minute arrival counts. We limit the data sample to periods when the airport was in a south flow configuration. Additionally, we only included 10-minute time periods when there were at least four total arrivals. All of the arrivals are then summed by month, and the difference between the most used and least used runways is expressed as a percentage of total arrivals. The result of this calculation, displayed in Figure 15, indicates that the difference between the most and least used arrival runways is reduced when pFAST is in use (lower values = better balance).

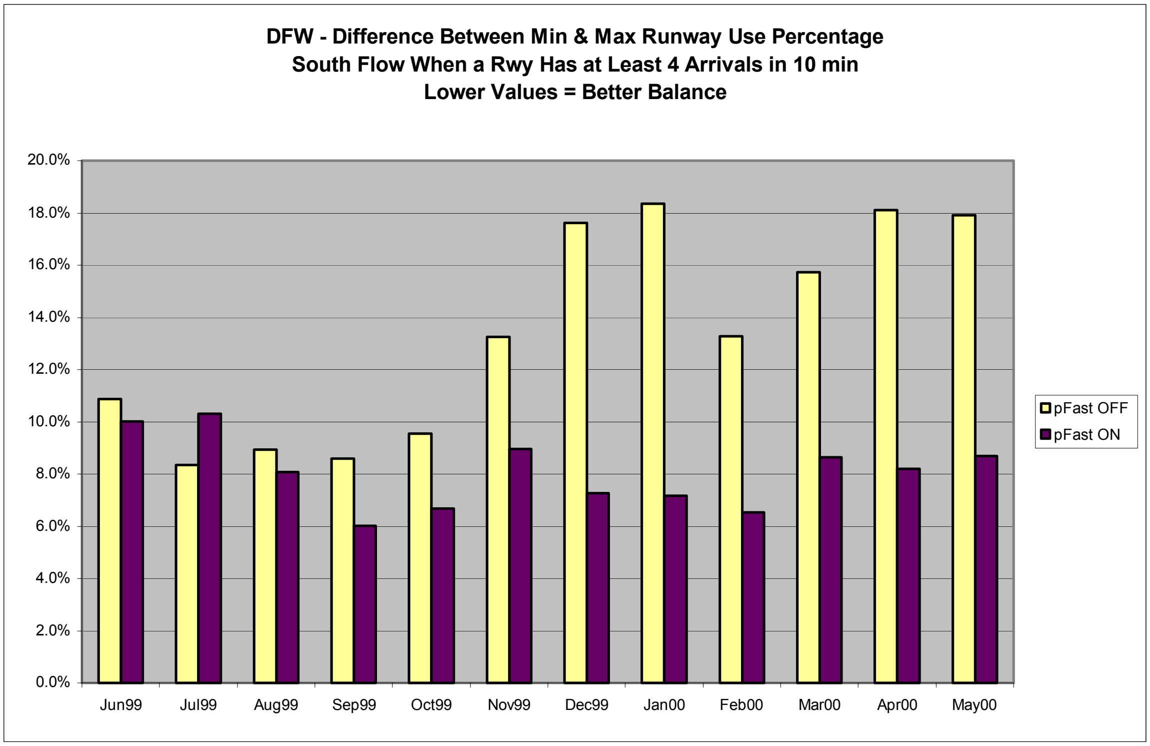

Figure 15. DFW Arrival Runway Balance

3.12 Supplemental Analysis of Increased Operations (Arrivals and Departures)

A more detailed analysis was performed on the effect of pFAST on operations (arrival plus departures). During the course of the study, we found, through analysis and discussions with facility personnel, that the benefits attributed to an increase in operations are based on two sources. The primary benefits are derived from the automation itself – that is, improvements measured when the automation is in use. Secondary benefits are seen as improvements induced by the traffic management initiative and enabled by the automation.

The study sought to answer the question of pFAST's effect on total operations during peak periods at DFW. Again, the data used in this study was derived from DFW TRACON Traffic Management logs, which documents arrivals and departures in 10-minute intervals. The study period covered April 22, 1999 through March 31, 2000. An observation was defined as a single data point – a 30-minute peak in operations, plus attributes of that time period. A regression analysis was conducted to discern the combined effect of pFAST "on" versus "off" and the introduction of the new traffic management initiatives enabled by the pFAST automation.

To distinguish primary benefits from secondary benefits, a new indicator variable was created to represent the change in traffic flow management with respect to the usage of dual arrival fixes. This variable, POSTJUNE, was set to "0" through June 30, 1999, and set to "1" after that date.

The data were partitioned into two sets: visual approach conditions with four arrival runways and instrument approach conditions with four arrival runways. We used a test of means with variables of pFAST ("on" versus "off") and POSTJUNE (0 before July 1, 1 after that date) signifying the management initiatives enabled by the automation (see Section 3.3, DFW Management Initiatives). The test variable, HIGH8, is the total operations during 8 of the highest 30-minute periods per day.

Table 6 presents mean peak total operations values for visual approaches. During visual approaches the mean increase from pFAST off to pFAST on is 2.5 operations (113.58-111.05). The difference in the mean total operations between the pre July 1, 1999 and post July 1, 1999 variable is 5 operations (112.67 – 107.38). In total, the combined change in the mean related to pFAST and the post June management initiative variable under visual approaches is 7.5 operations (114.04 - 106.48). These differences are statistically significant at the $\alpha = .05$ level of significance.

Table 6. PFAST and POSTJUNE Effects on Total Operations (Visual Approaches, 4 runways, HIGH8 >=70)

	Sample Size			**Mean Peak Operations**		
	POSTJUNE			**POSTJUNE**		
PFAST	**0**	**1**	**Total**	**0**	**1**	**Total**
0 (off)	185	1055	1240	106.48	111.85	111.05
1 (on)	73	630	703	109.67	114.04	113.58
Total	258	1685	1943	107.38	112.67	

Table 7 presents mean peak total operations values for instrument approaches. During instrument approaches the mean increase from pFAST "off" to pFAST "on" is 4.8 operations (108.35 – 103.53). The difference in the mean total operations between the pre July 1, 1999 and post July 1, 1999 variable is 4.2 operations (107.08 – 102.89). In total, the combined change in the mean related to pFAST and the post June management initiative variable under instrument approaches is 8 operations (109.97 – 101.92). These differences are statistically significant at the $\alpha = .05$ level of significance.

Table 7. PFAST and POSTJUNE Effects on Total Operations (Instrument Approaches, 4 runways, HIGH8 >=60)

	Sample Size			**Mean Peak Operations**		
	POSTJUNE			**POSTJUNE**		
PFAST	**0**	**1**	**Total**	**0**	**1**	**Total**
0 (off)	155	200	355	101.92	104.78	103.53
1 (on)	75	159	234	104.91	109.97	108.35
Total	230	359	589	102.89	107.08	

An additional analysis was conducted by MITRE/CAASD where they studied in more detail the result of the traffic management initiative that occurred on July 1. The results of this analysis are similar and can be found in Blucher, et al, July 2000.

3.13 Valuation of Measured Operational Impacts

3.13.1 Overview of Potential Benefits

NAS modernization automation, in this case pFAST, may bring about several forms of benefits to airspace users and service providers. In terms of air traffic management, the automation may increase traffic levels and the ability to move this increased traffic amount safely, adding predictability without increasing delays. To the major airlines, automation may show benefits in terms of reduced cost and increased revenue. Reduced cost may be measured in terms of lower block time with more predictable ground operations, i.e., fewer missed connections. The increase in revenue may be measured by the airline's ability to book more passenger connections, serve more markets, and add additional flights into the hub airport. The passenger benefits could be measured in increased services (resulting in lower trip time), a greater number of connections, and an increase in choice of flights.

The extent to which the airspace user and service provider will observe these benefits varies. In terms of "local" benefits, the improvement may be confined to a particular push - in the case of pFAST, the arrival push. Local benefits may also be confined to a single airport and to specific pushes. In the case of pFAST at DFW for example, analysis showed that the top 3 arrival pushes each day observed minimal benefit from pFAST whereas the top 8 arrival pushes each day saw measurable improvement in several performance areas. Lastly, local impacts may be categorized as the airline's ability to maintain and possibly increase their arrival bank integrity. Local benefits may be extended to subsequent departure pushes in terms of on-time departures. They may also be extended system-wide in the form of improved on-time arrival and departure at other airports served by the major airline conducting a hubbing operation at the affected airport.

In determining the valuation of an automation tool such as pFAST, three opportunities are considered. One opportunity is in reduced flying time in the terminal area as well as total block time (defined as wheels-off to wheels-on). A second opportunity may be observed in the reduction of variance in arrival times, which can lead to improved bank integrity. This can be measured as an increase in on-time arrival performance as well as a decrease in the percentage of flights arriving "late." Thirdly, the added throughput during an arrival push prompts estimates of increased passengers itineraries. The airline can now book passengers on earlier departing flights as well as add flights to the affected arrival push and subsequent departure push.

With the presence of the above-mentioned short-term benefits, the airspace user can focus on longer-term benefits such as those derived from airline schedule changes. With the persistence of the short-term benefits, that is, an increased capacity in the arrival push at DFW, the airline schedule may soon reflect additional flights in the DFW arrival banks.

3.13.2 Valuation of Operational Impact of pFAST at DFW

The derivation of the economic impact of pFAST at DFW focused on specific airline cost and revenue effects stemming from the observed increase in operations during peak periods. The analysis captures the net revenue enhancements from an improved quality of service available to passengers at DFW. Several qualifying assumptions were made:

1. No evaluation of gain or loss of passengers between one carrier and another at DFW;
2. No evaluation of gain or loss to a hubbing airline's network at other airports; and
3. No evaluation of gain or loss of passengers for DFW hubbing carriers versus other carriers at different hub airports.

The analysis focused on three areas of potential benefit. Before an airline schedule change, the analysis calculated the increased revenue from improved passenger connections for a hubbing airline and also the increased revenue from higher passenger willingness to pay due to improved on-time performance for affected airlines and flights at DFW. After an airline schedule change, we calculated the improved annual net revenue from scheduling additional arrivals during the peak periods. This was made from the perspective of a hubbing carrier at DFW.

The effect of pFAST was measured to be an increase in arrivals *and* departures during periods of peak operations at DFW. The results of the operational impact analysis are such that an average of an additional 8 operations are handled in each of 8 30-minute peak periods each day. The overall benefit to passengers can be captured in annualized airline revenue. Passenger benefits result from increased on-time performance, which leads to increased passenger connection opportunities. Thus, the increase in revenue stems from more available itineraries and increased ticket sales.

The increase in the number of added peak operations leads to a substantial amount in the annual net revenue. The major benefit of the added flights to peak operations stems from the opportunity to schedule additional arriving flights during the peak into the major carrier's hubbing operations. The additional arrivals are assumed to belong to the major hubbing airline carrying some connecting passengers. The percentage of passengers assumed to be connecting is 60 percent, while the other 40 percent have DFW as their final destination.

The increase in the number of arrivals in the peak period leads to the assumption that arrivals are landing "sooner" therefore increasing the airlines' on-time performance percentage. An analysis was conducted to prove this assumption. The arrival peak within the operations peak contains more flights and the period occurs earlier. Arrival on-time percentage in the operations peak is therefore expected to improve.

The assumptions on airline revenue implications and passenger benefits mentioned above are based on research conducted by MITRE/CAASD. The FFP1 Metrics Team offers this approach as a means of demonstrating other potential benefits derived from improved efficiency. Further details and potential airline revenue benefits were calculated and are presented in the MITRE/CAASD study, Blucher, et al., July 2000.

3.14 Future Sites

The FFP1 Metrics Team has begun data collection and some initial analysis of future FFP1 pFAST sites. The implementation schedule and analysis scheduled is presented in Table 8.

Table 8. pFAST Implementation and Evaluation Schedule

Site	Data Collection Begins	Initial Daily Use (IDU)	Planned Capability Available (PCA)
Atlanta	March 2000	19 March 2001	17 September 2001
Los Angeles	February 2000	9 February 2001	10 August 2001
Minneapolis	June 2000	14 June 2001	13 December 2001
St. Louis	October 2000	30 October 2001	30 April 2002

Data collection has begun for the Los Angeles (LAX) implementation of pFAST. ARTS data from the Southern California TRACON is being collected, as well as the TMU log files from the TRACON. ARTS data is also being collected at Minneapolis and Atlanta. All of this baseline data is being imported into the FFP1 Metrics database (discussed in Section 7.0 of this report) for use in the operational impact evaluation once the FFP1 capabilities are implemented.

3.15 Previous pFAST Analyses

A detailed field evaluation of a prototype pFAST system was conducted by Crown Communications and Seagull Technology Inc. at the DFW TRACON between February 12 and July 12 1996 (Reference 14). This evaluation occurred prior to the redesign of DFW airspace and the beginning of operations of the fourth arrival runways, so the results are only partly applicable. Nevertheless, it is instructive to review these previous results, as they are consistent with our more recent findings documented in this report.

Crown Communications collected and analyzed arrival, departure, and surface data during pre-peak, peak, and post-peak periods. The use of pFAST was found to significantly improve all of the metrics examined save one (taxi time), for which there was no discernable change. The results are summarized below.

Arrival Rates – pFAST usage increased arrival rates by 4.9 aircraft per hour on average. Arrival rates were increased for low as well as high TRACON demands.

Runway Balancing – pFAST improved pre-peak and peak period runway balancing. The difference between the most and least used runways arrival counts decreased from 17.6 percent to 9.4 percent in pre-peak periods, and from 5.2 percent to 3.5 percent in peak periods.

Final Approach Inter-Arrival Spacing – Mean peak period inter-arrival spacing decreased from 91.9 seconds to 87.8 seconds with pFAST usage.

TRACON Delay – pFAST usage decreased pre-peak, peak, and post-peak mean TRACON flying times by 42 seconds, 44 seconds, and 32 seconds, respectively.

Total Airport Operations – Total airport throughput (arrivals plus departures) was found to increase by 13 percent with pFAST usage.

Taxi Times – No significant change in taxi-in or taxi-out times was observed.

Departure Queues – pFAST resulted in a 9 percent reduction in departure queue length. An overall increase in departure rates was also observed.

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4.0 TRAFFIC MANAGEMENT ADVISOR (TMA)

4.1 Description

The Traffic Management Advisor (TMA) component of the Center TRACON Automation System (CTAS) assists controllers in the enroute cruise and transition airspace around major airports by providing them with a means of optimizing arrival throughput. By optimizing throughput, TMA helps to reduce delays in the extended terminal area (defined as within 200 nmi of the arrival airport). Inputs to the TMA system include real-time radar track data (i.e., aircraft position in three dimensions), flight plan data, and detailed local meteorological data. TMA's trajectory models use this information, updated every 12 seconds, to compute routes and optimal schedules to the meter fixes for all arriving aircraft which have filed IFR flight plans, with consideration given to separation, airspace, and airport constraints.

Managers in the center Traffic Management Unit (TMU) use TMA as a strategic planning tool, and controllers use it tactically by actively controlling aircraft. The TMA computer interface incorporates two primary strategic displays. The Timeline Graphical User Interface (T-GUI) displays estimated time of arrival, CTAS delay-imposed scheduled time of arrival, per aircraft delay, and runway assignment for each track in the TMA area of regard. The Planview Graphical User Interface (P-GUI) displays a planview depiction of arriving aircraft. TMU managers use these and other displays to determine if and when aircraft metering will need to be imposed in the center's airspace so that the arrival rate specified by the TRACON is not exceeded. When metering is imposed, floor controllers will see a sequence list overlaid on their radar displays that indicates which aircraft will need to be delayed and by how much.

Table 9. TMA Deployment Schedule

ARTCC	Airport	Initial Daily Use Date
ZMP	Minneapolis/St. Paul	27 June 2000
ZDV	Denver	6 Sept. 2000
ZLA	Los Angeles	23 Nov. 2000
ZTL	Atlanta	22 Feb. 2001
ZMA	Miami	23 May 2001
ZOA	San Francisco	3 Sept. 2001
ZAU	Chicago	31 Dec. 2002

The planned deployment schedule for TMA is shown in Table 9. The system has been operational at ZFW (handling DFW arrivals) since June 1996, and the airspace surrounding DFW underwent a significant redesign in October 1996. Since baseline data is required in order to gauge the impact of the tool at a particular location, and since TMA has been in virtually uninterrupted use at DFW since the airspace redesign, no baseline data is available with the current airspace design. Thus, we have been unable to analyze the performance of TMA at ZFW (see Reference 1). Previous studies of TMA at ZFW have been conducted and are summarized below. We do plan to analyze the performance of TMA at all of the other centers indicated in Table 9, however, and we have collected a significant amount of baseline data for Minneapolis (the next TMA deployment location). This data has been ingested into our Oracle database at the FFP1 Program Office and will be used to assess the impact of TMA at Minneapolis once the system becomes operational.

4.2 Previous Analyses

Several previous analyses of TMA performance have been conducted in the past five years in association with prototype field trials. In January and February 1996, Crown Communications, Inc. conducted an assessment of TMA Build 1. (Reference 2). Overall this study concluded that TMA Build 1 delivered "substantial service provider benefits in the management of Denver arrival traffic," and that the system also delivered "user benefits at Denver by allowing rapid airport reconfiguration to provide more direct routings from the meter fixes to the runways." During this assessment the system was frequently described by Traffic Management Coordinators as "invaluable" and "indispensable."

Crown Communications, Inc., conducted another assessment of TMA in July of 1996, this time of the Build 2 system at Ft. Worth Center (Reference 3). This study reexamined the accuracy of scheduled meter fix arrival times for both TMA and Arrival Sequencing Program (ASP), the system that TMA is designed to replace. The study found a significant decrease in both the mean and standard deviation of meter fix arrival time errors with TMA (see Table 10). This observed improvement in meter fix scheduling accuracy was then used to predict an improvement in runway inter-arrival spacing using the *Airport Delay Model*. The model predicted that TMA would result in an inter-arrival spacing reduction of between 2.20 and 2.96 seconds, which would result in airline direct operating cost savings of $1.37 per rush arrival or from $2.12 to $2.96 million per year.

Table 10. DFW TMA Field Assessment Scheduling Accuracy Results

	Mean (sec.)	Standard Deviation (sec.)
ASP Meter Fix Scheduling Error	139	187
TMA Meter Fix Scheduling Error	-19	105

Finally, in February 1998, Seagull Technology, Inc. estimated the potential delay and fuel savings resulting from implementing TMA and pFAST at a number of airports (Reference 4). Assuming that TMA would improve meter fix scheduling accuracy by 90 seconds on average, and reduce the variation of scheduling error by 90 seconds, Seagull concluded that TMA would result in annual operating cost savings of between $580,000 and $1,230,000 with 1996 traffic levels, or between $1.11 and $2.37 million per year with 2005 traffic levels.

4.3 Recent Anecdotal Benefits

As mentioned previously, we have not attempted to measure the impact of TMA at DFW this year because the system is in use virtually continuously and we have no applicable baseline data. Nonetheless, long-time air traffic managers at the Ft. Worth center report that TMA usage has resulted in an increase in airport acceptance rates of approximately six aircraft per rush. If we assume that this increase in arrival rate affects six of the nine rushes, then it may be concluded that TMA has provided the potential arrival capacity at DFW for an additional 36 flights per day at peak periods.

Alternatively, we can convert this increased arrival capacity into delay reduction for the existing arrival traffic. If we assume that 60 aircraft arrive in each rush, and these arrivals are evenly distributed over a 30-minute period, one aircraft arrives every 30 seconds. If the capacity is increased to 66 arrivals in a 30-minute period, one aircraft will arrive every 27.3 seconds. Thus, the interarrival gap has been reduced by 2.7 seconds, on average. This impact is cumulative throughout the rush; the 30^{th} (or average) arrival of the rush will avoid 81 seconds of delay. Multiplying this average delay savings by six rushes per day and 60 aircraft per rush, we come up with a daily delay savings of about 490 minutes. Over the course of a year this translates to 3,000 hours of delay savings.

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5.0 COLLABORATIVE DECISION MAKING (CDM)

5.1 Description

Collaborative Decision Making (CDM) was conceived out of the FAA's Airline Data Exchange (FADE) experiments that began in 1993. These experiments proved that having airlines submit real-time operational information to the FAA could improve air traffic management decision-making. CDM is an effort to improve air traffic management through information exchange, procedural improvements, tool development, and common situational awareness.

The initial focus of CDM, known as Ground Delay Program Enhancements (GDP-E), began its prototype operations at San Francisco (SFO) and Newark (EWR) airports on January 20, 1998. Under GDP-E, participating airlines send operational schedules and changes to schedules to the Air Traffic Control Systems Command Center (ATCSCC) on a continual basis. This schedule information includes, but is not limited to, flight delay information, cancellations, and newly created flights. Through the use of the Flight Schedule Monitor (FSM), the ATCSCC uses this information to monitor airport arrival demand and to conduct ground delay programs (GDPs). The airlines are also able to monitor arrival demands and model ground delay programs via FSM but do not have the capability to alter or implement ground delay programs.

In addition to improving the execution of GDPs, CDM has been found to have application to other air traffic management problems, such as airspace congestion due to heavy traffic or en route weather. CDM's Collaborative Routing (CR) function is intended to provide better information to airspace users about potential flow problems that are likely to require rerouting or other flow management actions. This may allow users to prepare for possible effects on their operation in advance. The National Air Space Status Information (NASSI) function will provide a mechanism to share critical safety and efficiency data with NAS users.

5.2 Summary of CDM Performance Metrics

The following sections present a list of metrics and summary discussion of the results that were identified by the CDM Working Group, which was comprised of FFP1 analysts, airlines, ATC specialists, academia, and system developers. Selected metrics were determined to be representative of the operational impacts that would be expected from better data quality, timeliness, and slot allocation under GDP conditions. The analytical approach, established in concert with the RTCA, was to compare representative metrics of operational performance both pre- and post- CDM implementation. The intent is to identify quantitative evidence that desired changes in operational performance have been achieved.

For a thorough discussion of the rationale for choosing these metrics, as well as the results of the analyses, please reference the January 2000 report, "An Operational Assessment of Collaborative Decision Making in Air Traffic Management: *Measuring User Impacts through Performance Metrics*." This document was a collaborative effort incorporating the expertise of many organizations in the FAA and aviation industry.

5.3 Improved Data Quality

CDM has produced new information by combining FAA and airline data sources. All CDM airline participants have implemented data feeds from their operations systems into the CDMnet. Using these data feeds, the airlines provide information on flight cancellations, mechanical delays, and other events that impact the demand on the NAS. This information is merged with FAA-generated information by systems at the Volpe Center into a real-time data feed, known as the "CDM String."

Through the CDMnet, the CDM-enhanced information has been distributed in an unprecedented fashion. In fact, probably the most significant aspect of the new CDM information infrastructure is that the Airline Operations Centers (AOCs) receive the same information and decision support tools, as do FAA ATCSCC specialists. Such information is critical in enabling airline operations specialists to plan responses to changing conditions and possible FAA control actions. Previously, such information was not available to airline operations planners or was only available "after-the-fact," when it could no longer be used to influence decision making.

Our analyses have found that the information flowing over the CDM string is of higher quality - greatly improving NAS system predictability. Moreover, we have found that the improvements are most dramatic under bad weather operations.

5.4 Improved EDCT Compliance

Estimated Departure Clearance Time (EDCT) refers to the FAA-assigned time at which a flight is supposed to depart under a GDP. The successful execution of a GDP depends heavily on departure compliance. However, failure to comply with the EDCT during GDPs has been a problem for years. CDM has been providing airlines with real-time airport arrival information and has encouraged airlines to focus on EDCT compliance in a collaborative manner.

We have found that departure compliance has improved significantly under CDM. The average on-time departure percentage has increased from 50.85 to 65.87 percent of all flights issued an EDCT. This means that 15.02 percent more flights maintain departure compliance since the inception of CDM. This implies that the number of on-time departures has grown by 29.54 percent.[9]

The 15.02 percent growth in on-time flights can be decomposed into a 10.34 percent reduction in early departures and a 4.68 percent reduction in late departures (15.02 = 10.34 + 4.68). These correspond to 21.76 and 37.41 percent reductions in the respective categories. Airlines have always had an incentive to reduce late departures regardless of CDM status. This may be the reason why we see less improvement in this category compared to improvement in early departures. Nevertheless, the 21.76 percent late departure improvement over the pre-CDM period is a significant achievement. The improvement in early departures over the pre-CDM period is 37.41 percent. We believe that this improvement is resulting from an active information exchange between the FAA and airlines and improved attention toward flight operations.

[9] Taken with respect to the original percentage of on-time flights (i.e., $29.54 = 100 \times [15.02 / 50.85]$).

5.5 Improved Predictability: Integrated Predictive Error - The IPE Metric

CDM has made a concerted effort to improve the accuracy of flight departure predictions. Participating air carriers have voluntarily augmented ETMS flight data with their own departure predictions. The premise is that each airline has the most complete picture of its operations (delays due to connectivity, gates, etc.), thus enabling it to make more accurate predictions of its departure times than ETMS.

We used the integrated predictive error (IPE) metric to monitor long-term trends in flight departure predictive accuracy. IPE is a weighted average of the errors in a stream of predictions made over time for a single event. Based on the data used in this analysis, we have found that, on average, departure prediction accuracy increases (has less error) as a departure flight approaches. Since August of 1997, the average departure prediction error on GDP days at San Francisco Airport (SFO) has dropped from 31.29 minutes per flight to 26.06 minutes per flight, for a net reduction of 5.23 minutes per flight. Comparable results have been found at Newark Airport (EWR).

The dramatic improvement on GDP days is noteworthy because accurate flight data is most crucial during a GDP. Average IPE values for non-GDP days at SFO and EWR have dropped as well. In fact, for both airports, the departure prediction error has been pushed below 15 minutes, the industry-wide standard for an on-time event.

5.6 Enhanced GDP Performance: The Rate Control Index (RCI)

The rate control index (RCI) measures the flow of air traffic into an airport and compares it to the targeted flow that was set by the traffic flow managers at the ATCSCC during a GDP. In other words, it is a measure of how well we executed the planning for a GDP. A single index, or percentage, is reported for the entire performance of a GDP on a single day. A higher score (e.g., 95 percent) corresponds to better performance, meaning the flow of traffic into the airport closely matched the targeted flow of traffic, both in quantity and in distribution.

The RCI metric is notable because it is designed to assess the execution of a program rather than the retrospective appropriateness of the plan underlying the program. When applied to traffic flow at the terminal space prior to any airborne holding, the RCI metric is virtually independent of the program goals set or the accuracy of the weather forecasts upon which it is based. In particular, RCI is adept at flagging GDPs with particularly high or low performance.

We tracked results of the RCI metric over a 30-month period for traffic flow into the terminal space of SFO and EWR airports, these being the two original CDM prototype operations airports. We found that traffic flow into both airports had improved slightly, more so at EWR than at SFO, meaning that the rate of flow tends to match more closely the targeted flow than it has in the past. In general, there tends to be more variation at EWR than at SFO. We attribute this to the complexity of EWR's terminal space (bordering on different traffic centers) and the less predictable nature of East Coast traffic. Also, we caution that the results at EWR are less conclusive than at SFO because the computation of this metric is dependent upon the modeling of airborne holding, which is more complicated at EWR than at SFO.

5.7 Reduced Near-Term GDP Cancellations

A near-term cancellation of a GDP is when a GDP is aborted within 30 minutes of its planned start time (the time at which the first controlled flight is scheduled to land). Since ground delay impacts flights prior to their airport departure, many flights will have absorbed delays well in advance of the start time of the GDP. Thus, all assigned ground delays absorbed prior to the start of the canceled GDP are (in hindsight) unnecessary. For this reason, near-term cancellations of GDPs are considered undesirable.

The number of instances of near-term GDP cancellations both pre- and post-CDM at six major airports was tracked. We conjectured that the combination of improved demand information and the power run feature of FSM that allows ATCSCC personnel to delay the implementation of a GDP to the last possible minute should decrease the number of near-term cancellations. Some airports showed improvement - others did not. Most notably, there has been a remarkable improvement at St. Louis in the percentage of near-term GDP cancellations. We believe that this is the result of superior data quality of the two major airlines that dominate the airport. This caliber of data quality is, in turn, attributed to the use of daily download, the replacement of (often) obsolete Official Airline Guide (OAG) information with fresh airline operational data at the start of each day (not all carriers participate in daily download). In addition, these airlines have provided positive feedback on FSM and the procedures adopted for CDM.

5.8 Increased User Equity

Enhancements to GDPs introduced a new process for making the initial assignment of flights to arrival slots during a GDP. Through experimentation and dialogue, the air carriers and the FAA have worked hard to make this rationing process equitable to all parties involved in a GDP. The result of their efforts is an algorithm called Ration-by-Schedule (RBS). RBS rations arrival slots according to scheduled arrival times as posted in the OAG, as opposed to real-time, estimated arrival times. This removes disincentives for airlines to notify the ATCSCC of delays and establishes the concept of slot ownership.

We designed four metrics to assess the equity of the current arrival slot allocation process. Based on an evaluation of these metrics, the RBS algorithm has proven to be a fair and equitable mechanism for assigning arrival slots to flights during a GDP. Moreover, the decision support tools embedded within FSM provide GDP equity statistics which may be used by ATCSCC specialists' to model various GDP options.

5.9 Tailored GDP's through Revisions

The modification of GDP parameters such as scope, duration, or the associated AAR is known as a revision. Prior to CDM, the ATCSCC did not have the capability to revise a program once it was in effect. While they did have the ability to affect GDP-controlled traffic flow by means such as blanket delays (adding a fixed number of minutes of delay to all flights), the methods for program modification were cruder and less effective than the revision capability now provided by CDM.

One of the most powerful revisions that can be made to a GDP is to extend the length of a program. This allows the ATCSCC to control later-arriving traffic when adverse weather effects last longer than expected, and to smooth out pent-up demand (a stack) that may accumulate toward the end of a program. Since GDP revisions were not an option prior to CDM, we were not able to make a pre- vs. post-CDM analysis of the effect of this tool. However, we can state that this tool has been used frequently since the inception of CDM and has proven to be highly effective for controlling traffic flow. At least 10 log entries in the ATCSCC GDP critique attest to the effectiveness of revisions to smooth out the traffic (and reduce departure delays). The flexibility of this tool has resulted in the fuller use of capacity and a reduction in airborne holding.

5.10 Compression Benefits

Compression is an inter-airline resource allocation algorithm that advances take-off times of flights to fill arrival slots vacated by cancelled or delayed flights. This makes more efficient use of airport arrival resources by utilizing arrival slots that would have been unused through initial slot allocation or the intra-airline substitution process. This reduces the number of minutes of planned (FAA-assigned) ground delay. Compression, which was introduced by the GDP enhancements of CDM, has proven to provide substantial benefits to the user community.

Between January 20, 1998 and March 31, 2000, there have been a total of 6,713,182 cumulative minutes of assigned ground delay reduced due to compression (and over 4 million cumulative minutes since the start of prototype operations). The benefits of these savings go beyond just averting needless ground delay. Compression provides the ATCSCC with a tool that helps create a smooth arrival rate into an airport, without wasting valuable arrival resources. As a result, the ATCSCC has more timely and accurate information about cancellations and delays. This allows the airlines and the ATCSCC to compress open slots (resulting from cancellations) that are not utilized through the substitution process.

Compression savings by airport have been tracked since the beginning of prototype operations on January 20, 1998. Figure 16 shows how the compression benefits have increased since the beginning of prototype operations. These compression benefits are displayed cumulatively over time. Three key events are highlighted on the graph: the start of all airports on September 8, 1998, the severe weather season over the winter, and the date in which the slot allocation algorithm was changed from RBS to RBS++ (compression included). It is clearly visible that the slope of the line increased at the “All Airports” mark, and then increased again for the snow season. The more GDPs that are run (and subsequently the more the number of compression cycles), the steeper the slope of the line will be. It has remained fairly steady since March 18, 1999.

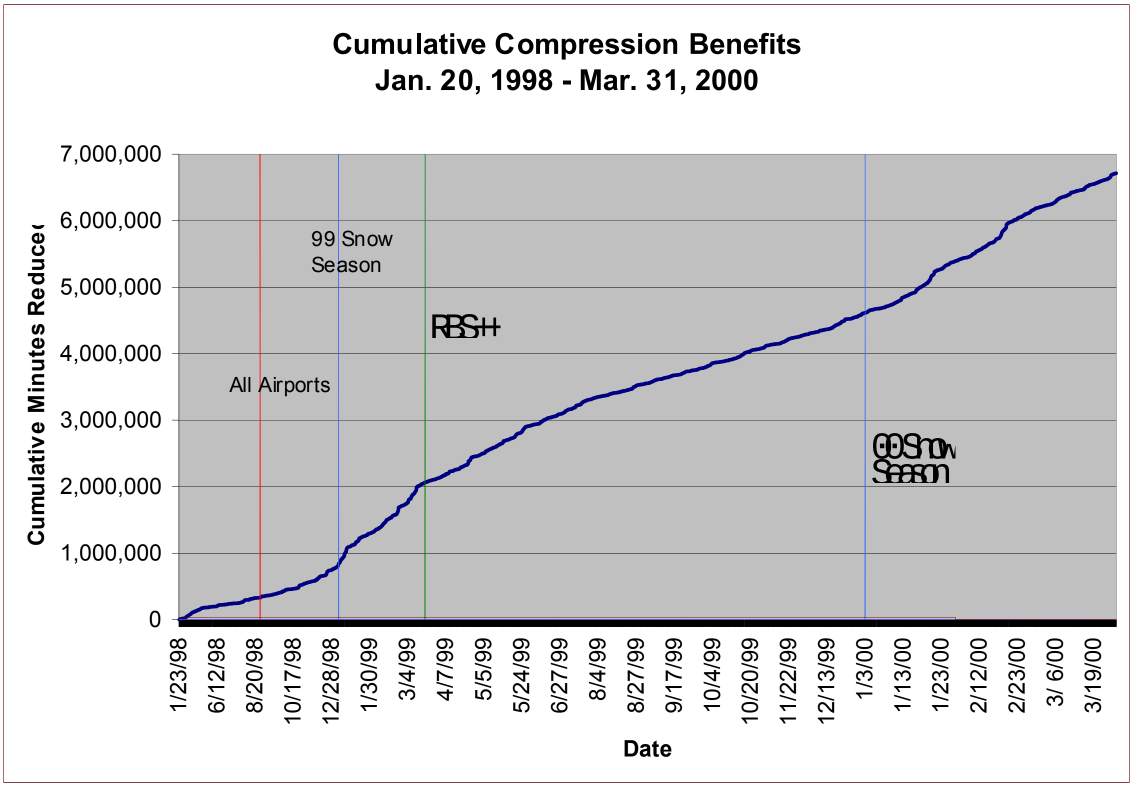

Figure 16. Cumulative Compression Benefits (January 20, 1998 – March 31, 2000)

Figure 17 shows the percent reduction versus percent traffic by air carrier. Percent change is defined as the percentage of total delay reduced on average due to compression. Traffic percent is simply the percent of the total traffic that is operated by that carrier. Starting on October 13, 1998, a policy change was made at the ATCSCC to include non-CDM-participating carriers in the compression process. Prior to that date, their flights were never moved up by compression.

The carriers are sorted by total minutes of delay reduced, but as can be seen, the percent reduction does not correspond with the total minutes reduced. Actually, UAL has a much lower percentage than many of the carriers. This is due primarily to their bridge-only status. Since they are a bridge-only in seven major hub airports, many of which frequently have GDPs, their compression benefits are lower than they would have been without the bridge-only status. UAL prefers to utilize the substitution process in moving flights up to fill open slots due to cancellations.

An interesting point to note is that the amount of traffic a carrier has does not affect the percent savings achieved through compression. All of the carriers with the smallest amount of traffic have significant percent compression savings. This proves the concept of how compression can significantly help the smaller carriers when the substitution process cannot.

The two data points that stand out with smaller percent reductions are “Other” and “GA/M.” The “Other” flights were not included in compression until October 13, 1998, and even then, they receive a lower priority in compression than the CDM-participants.

The fact that the “Other” percentage is so much lower than the other carriers shows the benefits to becoming a CDM-participant.

Most of the carriers listed in Figure 19 have been CDM-participants since the beginning of prototype operations. The exceptions are Midwest Express (MEP), and America West (AWE), who became participants on February 1, 1999, and Federal Express (FDX), which became a participant on February 16, 1999.

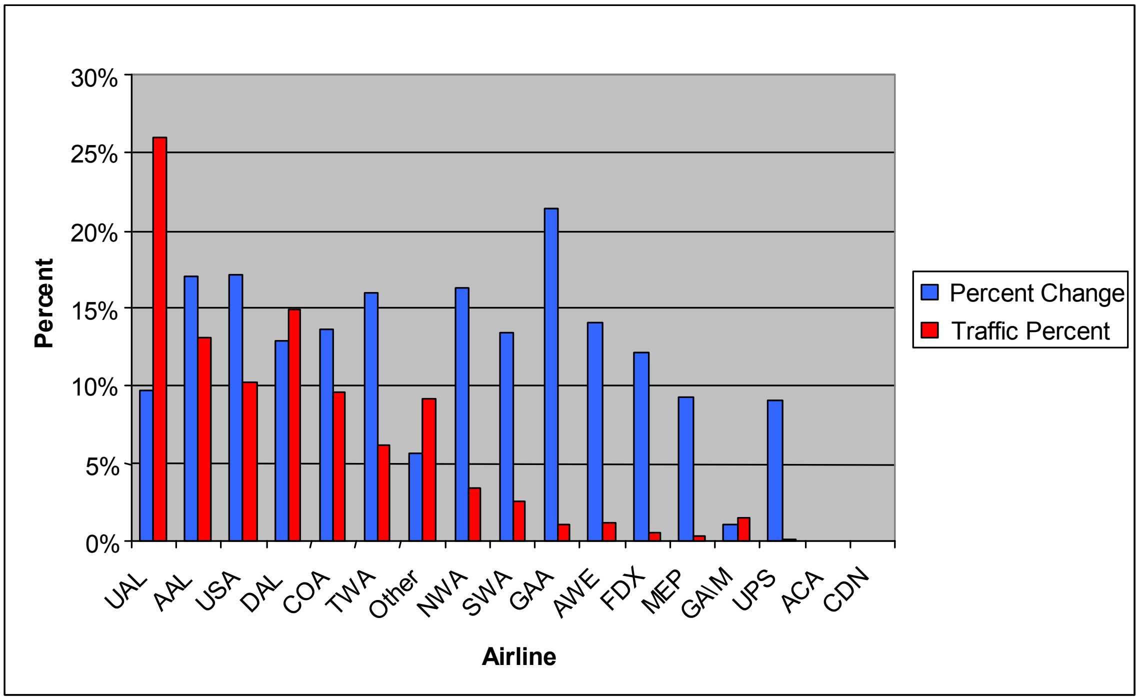

Figure 17. Percent Reduction vs. Percent Traffic by Airline (September 8, 1998 – July 15, 1999)

The compression process is used to ensure that no valuable arrival slots at an airport go unused during a GDP. This process can be run multiple times during the course of a GDP, as need dictates. The algorithm identifies open arrival slots due to flight cancellations and delays. It then moves other flights up, reducing their delays, to fill the vacated slots. Compression always attempts to fill an open slot by moving up a flight that belongs to the same carrier as the open slot. If that is not possible, it then tries to find a CDM-participating carrier that can benefit from the slot. Otherwise, the slot is made available to all flights.

Figures 16 and 17 represent analyses that track the number of minutes reduced to flights' estimated time of arrival every time a compression is run at the ATCSCC. These numbers have been recorded since the beginning of prototype operations on January 20, 1998. Since September 8, 1998, when CDM began operation at all airports, the numbers have been tracked in greater detail, including the delay reductions broken out by carrier. Starting on March 18, 1999, the delay reductions have also been tracked by individual flight.

Compression is a new concept introduced through CDM and as such there are no available baseline, or pre-CDM, data. This gives rise to the uncertainty of whether these benefits (in sum or in part) would have existed without the introduction of CDM. Prior to CDM, the carriers via the intra-airline substitution process could have achieved some of these reductions. We have quantified these possible airline-contributed reductions and significant benefits still exist that could have been achieved only through the CDM compression process.

6.0 SURFACE MOVEMENT ADVISOR (SMA)

6.1 Description

Surface Movement Advisor (SMA) provides aircraft arrival information to Airline Operations Centers (AOCs) and/or to airline ramp towers. At those airports where SMA is implemented, ARTS III data will be available. This data provides airline operations managers with the necessary information to remain informed of the status of arriving aircraft. Similarly, ramp controllers are able to use SMA to enhance user's gate and ramp operations. In short, the availability of this system facilitates greater collaboration between tower controllers and ramp personnel and provides real-time information for decision making.

ARTS III provides real-time data on arriving aircraft that may be used to facilitate accurate prediction of future traffic flows. ARTS III data includes information on aircraft identification and position in TRACON airspace, providing the necessary information to compute estimated touchdown times. Additionally, this data can allow users to better coordinate ground support operations, allocating resources such as ramp and airport services more efficiently.

Table 11 provides a list of SMA deployment locations, the dates deployment was completed, and the primary airline using the airport.[10] A proof of concept display has been developed for SMA by Metron Inc., which visually provides information on arriving aircraft and calculates arrival statistics including estimated time to touchdown (ETT).

Table 11. Deployment Sites and Primary Airlines Using SMA

Airport	TRACON	Date Deployed	Primary Airline
Philadelphia	PHL	December 1998	US Airways
Detroit	DTW	December 1998	Northwest Airlines
Dallas/Ft. Worth	DFW	November 1999	American Airlines
Chicago	C90	November 1999	United Airlines
Newark	N90	November 1999	Continental Airlines
Teterboro	N90	November 1999	General Aviation

6.2 Reported SMA Anecdotal Benefits

Based on the ability of the AOC and Ramp tower personnel to observe near real time location of aircraft in the terminal domain, operational improvements have been demonstrated at SMA locations. In the past, when AOCs were interested in knowing the exact location of aircraft in the terminal domain of an airport, they were forced to make a call to an FAA facility in order to get an accurate location. Enhanced Traffic

[10] The prototype version of SMA currently deployed at Atlanta Hartsfield airport (ATL) has been in operation since early 1997. The functionality of ATL SMA is somewhat more complete in that a sophisticated software application has been developed by NASA to enhance ground-monitoring operations at the airport.

Management System (ETMS) is also available, but because this data is limited to 4-minute updates, it does not provide the precision necessary for evaluating terminal area traffic flows. With the implementation of the ARTS III data feed and proof of concept display, AOC managers can now receive have aircraft location and estimated touchdown times in near real-time. This improvement in situational awareness in the AOC can be relayed to the pilot enabling improved decisions when a diversion is being considered. The ARTS data feed is also valuable to airline ramp tower operators in efficient management of gates.

Appendix A presents a copy of a letter from John Kern (Northwest Airlines) to Jane Garvey (FAA Administrator). This letter discusses the benefits that Northwest Airlines is currently experiencing with SMA. Specifically, the letter states; "The proof-of-concept display provides benefits to us (NWA) as real-time data is now available in our Systems Operation Center (SOC)." Further, it asserts; "Among other things, we expect more efficient coordination and management of ground support by Northwest Airlines personnel."

The following sections provide a discussion of additional SMA reported benefits and although the discussion is primarily qualitative, operational impacts are being witnessed regularly by many of the participating airlines. Many of these reported benefits can be translated into actual dollar savings.

6.3 Improved Situational Awareness to AOCs

Situational awareness in air traffic management (ATM) may be defined as the extent to which a user is cognizant of their immediate environment (i.e., the number, location, and destination of arriving/departing aircraft). It therefore follows that when situational awareness improves so does the potential for better and more accurate decision making and resource management

One example of improved situational awareness improving operations was referenced by Northwest airlines in the following situation. On January 12, 1999, (16:14Z), the NWA AOC notices an aircraft on a go-around. The AOC manager believes that the runway in which the aircraft was about to land on was declared as "breaking action nil" (or closed). After making a call to the city engineers who stated that they were unaware of the runway closure, the runway was quickly sanded and subsequently reopened about 15 minutes later. NWA has stated that this action may have saved at least 3-5 minutes in identifying the problem. Consequently, this action may also have prevented unnecessary go-arounds for 3-5 aircraft that were low on fuel. In this example, the availability of real-time aircraft accessible to stakeholders has increased the speed at which problems can be identified and solved.

6.4 Reduced Aircraft Diversions

Aircraft diversions primarily occur as a result of poor weather (reducing the airport acceptance rates), mechanical problems (forcing aircraft to land prior to their destination), or terminal congestion (resulting from unavoidable enroute and terminal delays). The SMA ARTS data feed can provide improved arrival time information during poor weather or other periods where there is terminal area congestion. Aircraft that are subject to significant congestion-related delays and lack fuel for holding are prime candidates for being diverted. With access to better terminal information airline dispatchers can provide pilots with more accurate information regarding their relative position to other aircraft and estimated arrival times.

NWA commented on the dispatcher's ability with SMA to describe to a pilot in detail where the aircraft was in the traffic flow along with an estimated touchdown time based on previous aircraft data. When making a decision to divert, pilots must take into account the quality of the data they are provided and often divert in situations where they could have remained on course. With more precise information, pilots are able to make informed decisions that avoid costly diversions.

Vince CeCi (NWA) estimates that on average NWA may avoid 3 or more diversions per week for aircraft destined for Detroit. In further discussions it became clear these avoided diversions occur during periods of significant TRACON congestion where touchdown times become more unpredictable.

The Metrics Team attempted to study SMA's diversion counts before and after SMA but found insufficient data and no means to reasonably normalize for weather. We did, however, consider the reasonableness of Mr. CeCi's estimates using high-level data. On average NWA has approximately 1600 diversions per year worldwide. NWA estimates Detroit to have approximately 20 percent of total diversions (or 320 per year). This amounts to approximately 6 diversions per week at Detroit. If SMA were to avoid 3 diversions per week we might expect a 50 percent drop in diversions. NWA's clarification of diversion avoidance occurring during highly congested traffic, normally driven by weather, would spread the approximate 320 diversions over a reduced time period. Assuming instrument meteorological conditions occur at Detroit approximately 20 percent of the time we can allocate the 320 diversions over 10 weeks which results in approximately 32 diversions per week during weather driven congestion at Detroit. To NWA and our Metrics Team it was determined that avoidance of 12 percent of diversions (3-5) during these weather impacted periods was reasonable.

NWA estimates the cost of each diversion to be approximately $5,000 to $50,000 depending on the aircraft and distance of the diversion. Assuming 80 avoided diversions per year this amounts to an estimated $400K to $4 million in annual savings at Detroit alone.

US Airways has found similar utility from the SMA ARTS III flight display l in observing terminal flight operations at PHL. Although no actual quantification of reduced diversions has been made, Jack Heinlein (USA) stated that the ability to quickly see the arrival flow, observe runway changes, use of the overflow runway, and observe departure flow and rates has also eliminated diversions at PHL.

Additionally, both airlines have indicated improvement in some cases in coordination with the TRACON to better manage (adjusting priority) those aircraft that are low on fuel.

6.5 Reduced Phone Coordination with FAA TMU

Sharing of the filtered ARTS III data provides all users in general and the airlines in particular with a channel that was previously not available to them. Historically, if the airlines had questions about aircraft in the terminal domain they were limited to calling an FAA facility to receive an answer. This process could take several minutes for each call. Over the course of a year the amount of time that might be spent on this process will add up possibly affecting user productivity. Thus, the new data has facilitated a near-term reduction in phone coordination by eliminating the need to ask questions now answerable with SMA.

In contrast to a reduction in the number of phone calls, the existence of previously unavailable data may also be contributing to calls that are more collaborative between the AOC and the FAA. Whereas before the installation of the ARTS III feed, calls to the FAA may have been more one-sided with the AOC managers asking questions rather than providing possible solutions. Now it appears that these calls may be more two-sided with a higher level of collaboration between both agents.

In one situation, noted by Tim Reid (NWA), NWA had an incoming 747 (full) from Japan that was late and considered to be high priority due a large number of connecting flights. Mr. Reid recalled the value of SMA in providing informational support in order to identify alternative solutions. Ultimately, NWA was able to propose a workaround to the FAA prioritized the 747 and minimized overall delay.

6.6 Improved Planning for Missed Approaches

Prior to SMA, if an aircraft missed an approach the AOC and ramp tower may not have been immediately aware of the required go-around or the aircraft's new ETT. This causes inefficiencies in ground related operations as resources are directed to the wrong gates awaiting the arrival of the aircraft. Although dispatch is unable to directly influence the position of the aircraft in the traffic flow, they do have the necessary information in which to calculate the new estimated time to touchdown. As a result, they are better able to plan for necessary gate changes and better position ground crews (e.g., baggage handlers, maintenance and fuel crews, and other support staff).

Improved Ground Operations

Installation of SMA at an airport ramp towers further facilitates airline ground operations. In February 2000, US Airways installed the ARTS III data feed at the PHL ramp tower with plans for deployment at the LGA ramp tower later this year. Based on evidence suggesting a decrease in taxi-in times, provided by Atlanta SMA, it may be that similar benefits may result from installation of SMA at other airport ramp towers.[11] Although detailed analyses have not been performed, US Airways managers maintain that SMA provides better and timelier information contributing to better tactical decision making, especially under irregular operations.

[11] For further discussion on reduced taxi-in times at Atlanta Hartsfield International Airport see, Surface Movement Advisor (SMA) Benefits Analysis, MCA Research Corp., October 14, 1997.

7.0 BASELINING ACTIVITIES

A crucial element of the FFP1 benefits assessment is the collection of baseline data at each of the FFP1 sites. Without adequate baseline data, we would be unable to gauge the impact of the FFP1 capabilities, since we would have nothing to compare against.

This section describes the FFP1 Metrics Team's baseline activities during the past six months. First we will review the data collection schedule and the current status of site-specific data. Next, we will discuss the Oracle database being developed by the FFP1 Program Office to house terminal-area metrics data. Finally, we will present some preliminary data collected from the Minneapolis/St. Paul International Airport (MSP) that is being used to understand their operation prior to this summer's initial operational use of TMA at Minneapolis center.

7.1 Data Collection Schedule

The FFP1 metrics data collection schedule is illustrated in Figure 18. Our intent is to collect baseline data for a period of one year prior to Initial Daily Use (IDU) at each site. In-use data will be collected for a period of one year following Planned Capability Available (PCA). By collecting one year's worth of data both before and after a system becomes operational, we hope to be able to separate any seasonal effects from the impact of the tool's implementation. Between IDU and PCA, data will also be collected with trends in the metrics reported in order to understand any "learning curve" effects.

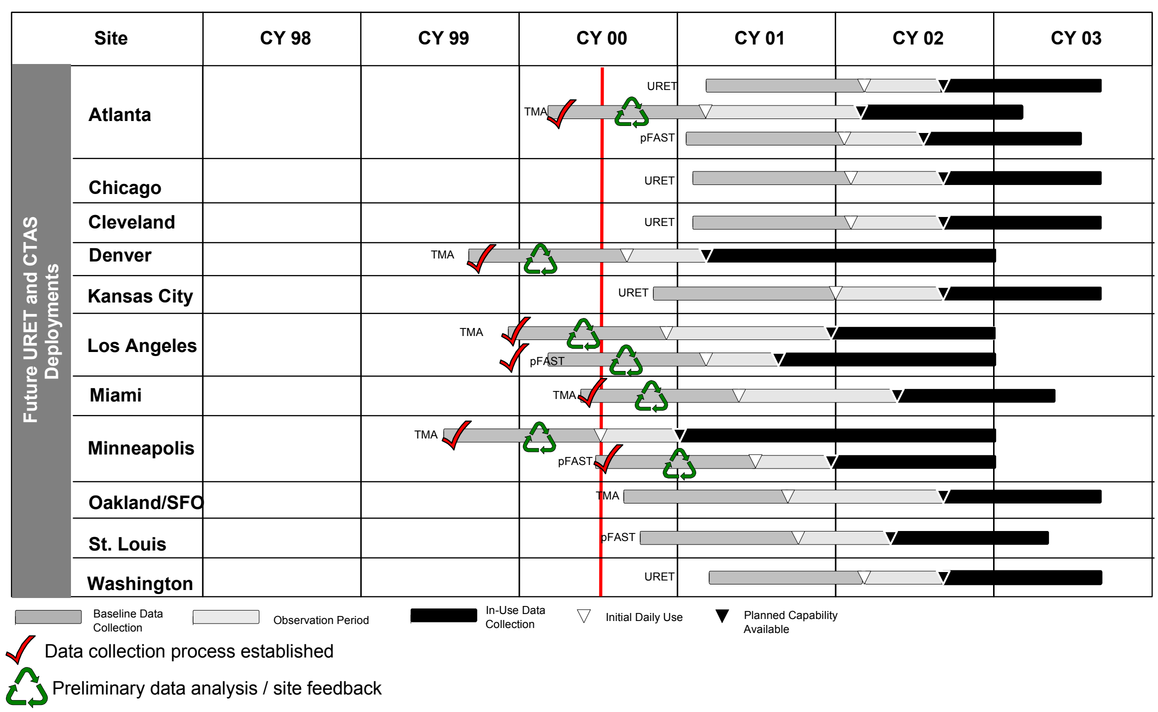

Figure 18. Metrics Data Collection Schedule

At the current time, we have begun collecting baseline data at Atlanta, Denver, Los Angeles, Minneapolis, and Miami centers and at the Southern California and Minneapolis/St. Paul TRACONs, and are thus on schedule.

7.2 Oracle Database Development

Data from a number of disparate data sources will be required to conduct the benefits analyses described in Reference 1. Since it would be inefficient for analysts to access these data sources directly and repeatedly perform their own data integration, we have developed a data warehouse using Oracle software, which is hosted on a Windows NT server at the Free Flight Phase 1 Program Office. The database currently is being used to house extended terminal area radar data on a per flight basis, along with associated airport and weather data, and as such contains an unprecedented quantity of detailed flight tracks and associated metrics.[12] As the database currently includes only extended terminal area data, it is initially intended for use in analyzing the performance of TMA and pFAST, although it's use could be expanded for URET analyses with the inclusion of en route data.

The FFP1 performance measurement database incorporates data from three primary data sources: ARTS/Host data, NCDC weather data, and airport log data. The ARTS/Host data provides the arrival/departure flight information such as the flight identifier, aircraft type and model, flight plan, and radar track. Thus, this data can be used to determine the arrival rate, distance traveled between two defined points, time required to travel between two defined points, and the time of arrival at the runway threshold. In addition, the flight plan provides the planned time of arrival. Obviously, this data source provides the majority of the raw data and metrics necessary to analyze the TMA and pFAST tools.

The NCDC data provides a description of the weather, temperature, visibility, and wind at the airport surface. Airport log data provides the acceptance rate, configuration, and restrictions in force. These two data sources provide independent parameters that affect the operational performance of the site.

The performance measurement database is comprised of four parts: data ingestion software, the raw data database, the analysis database, and the data wrapper. The data ingestion software prepares the data available from the data sources and populates the tables in the raw database. The raw database contains tables that store flight and track information, weather at the airport, and airport conditions. The analysis database contains tables that will be used to baseline the facility and quantifies the benefits of the delivered tool. Finally, the data wrapper creates the metrics analysis tables from the data in the tables in the raw database. Figure 19 illustrates the overall architecture. For more information, see Reference 5.

[12] While there are several FAA-sponsored databases that contain en route or single airport terminal area data, to our knowledge there has never before been an attempt to collect radar track data from many airports over several years in one convenient database.

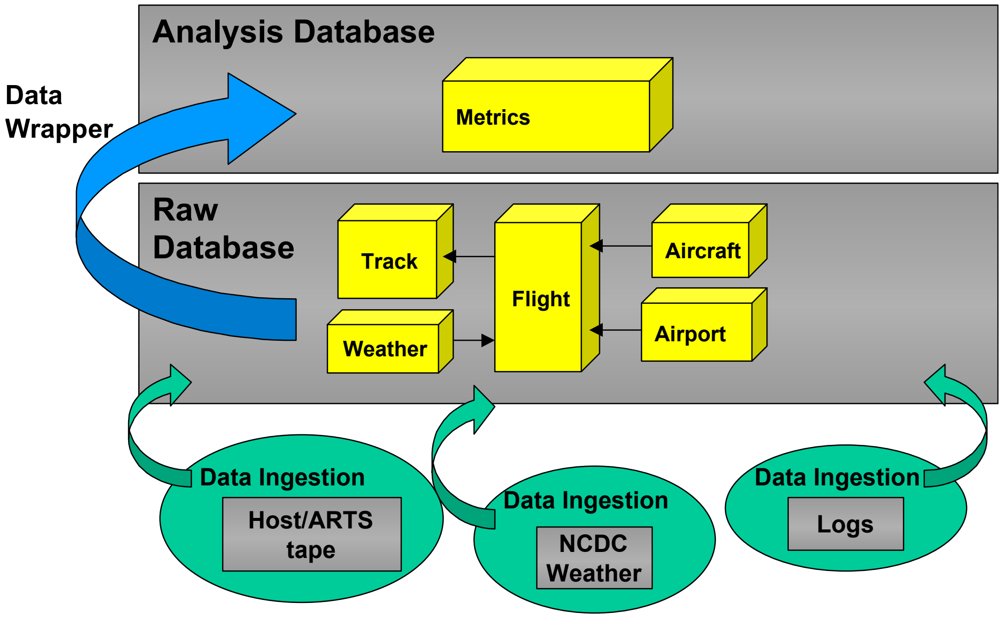

Figure 19. Metrics Database Architecture

7.3 Minneapolis/St. Paul Data

Minneapolis center is the next facility to go operational with a CTAS tool (specifically, TMA), so for nearly the past year we have been collecting Host and ARTS radar data for arriving traffic at MSP along with airport log and weather data. Thus far, we have approximately 155,000 arrival tracks in the FFP1 Performance Measurement Database, which comprise over 38 million radar hits.

Figure 20 illustrates 100 representative radar tracks for arriving traffic at MSP superimposed over the Minneapolis center and MSP TRACON boundaries. Also illustrated in this figure are several range rings, which we use for metric calculations (e.g., flight time and distance from the 200 nmi range ring to the meter fix). Figure 21 presents a more detailed view of arrival tracks at MSP on 26 September 1999 (the octagon represents the TRACON boundary). On this day the airport was using runways 30L and 30R for arrivals. The preponderance of arrivals from the south and east is evident in both of these figures. Figure 22 presents the number of arrivals by direction for each day in March 2000. From this figure it is obvious that most MSP arrivals come from southeast of the airport.

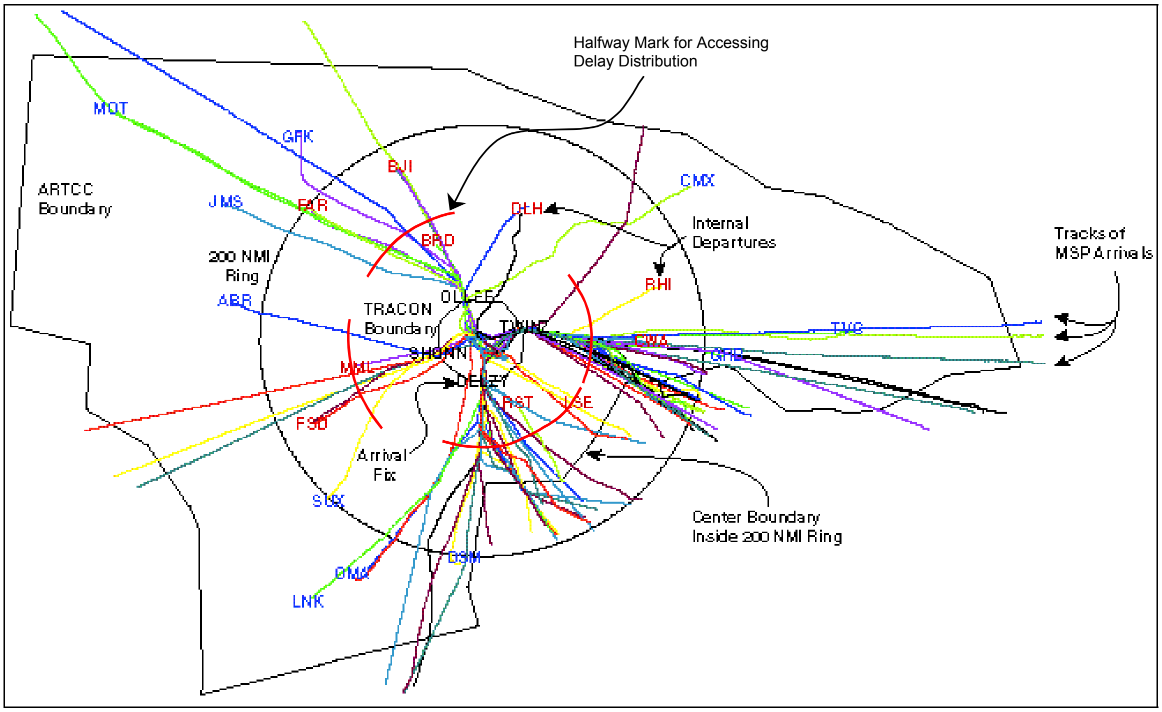

Figure 20. Representative MSP Arrival Tracks, Minneapolis ARTCC

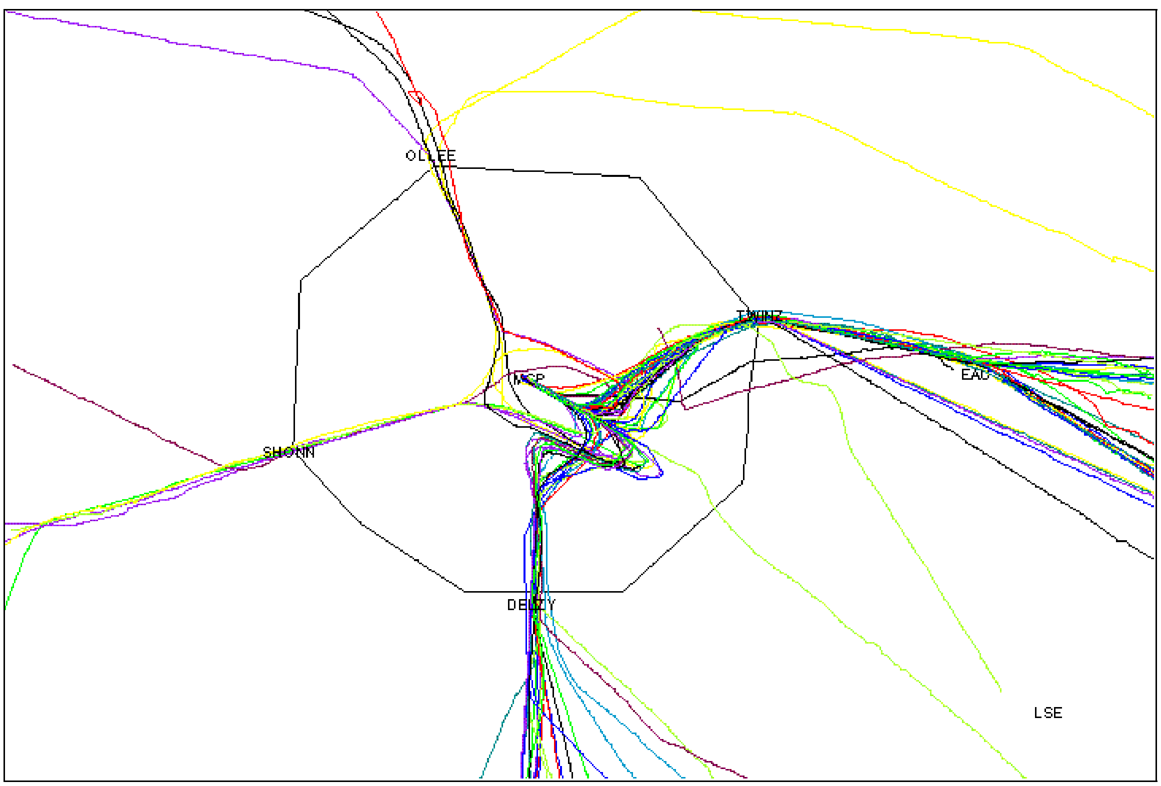

Figure 21. Representative MSP Arrival Tracks, MSP TRACON

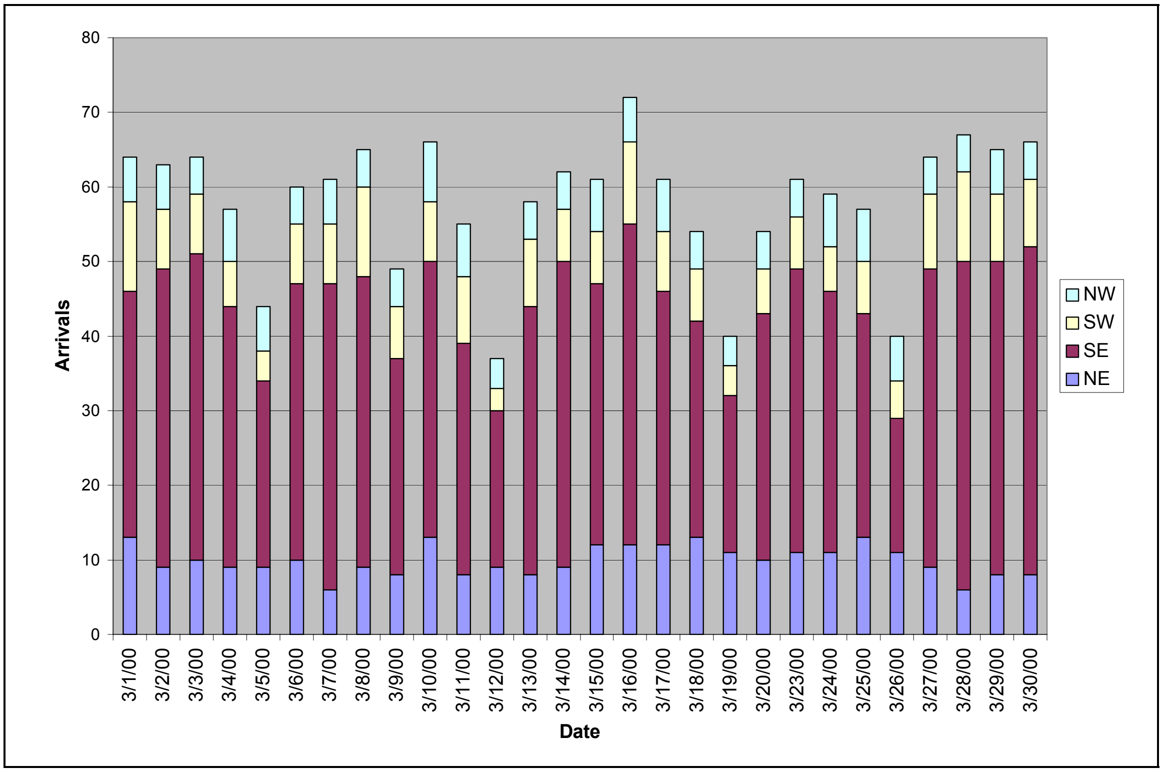

Figure 22. MSP Arrival Fix Balance, March 2000

Since the ability to increase arrival rates is one of the objectives of implementing pFAST and TMA, we have spent considerable time developing techniques for identifying arrival "pushes," quantifying arrival rates, and analyzing the resultant data. Figure 23 illustrates MSP arrival rates as a function of time of day for 15 days in December 1999. The data used to compute these rates are computed in 15-minute periods. Figure 25 illustrates the fact that daily arrival banks at a hub airport such as MSP are fairly repeatable, at least when the weather is benign. Figure 24 illustrates cumulative arrivals as a function of time of day for one week in March 2000; by plotting arrivals cumulatively in this manner it is not necessary to select a period of time over which to calculate rates.

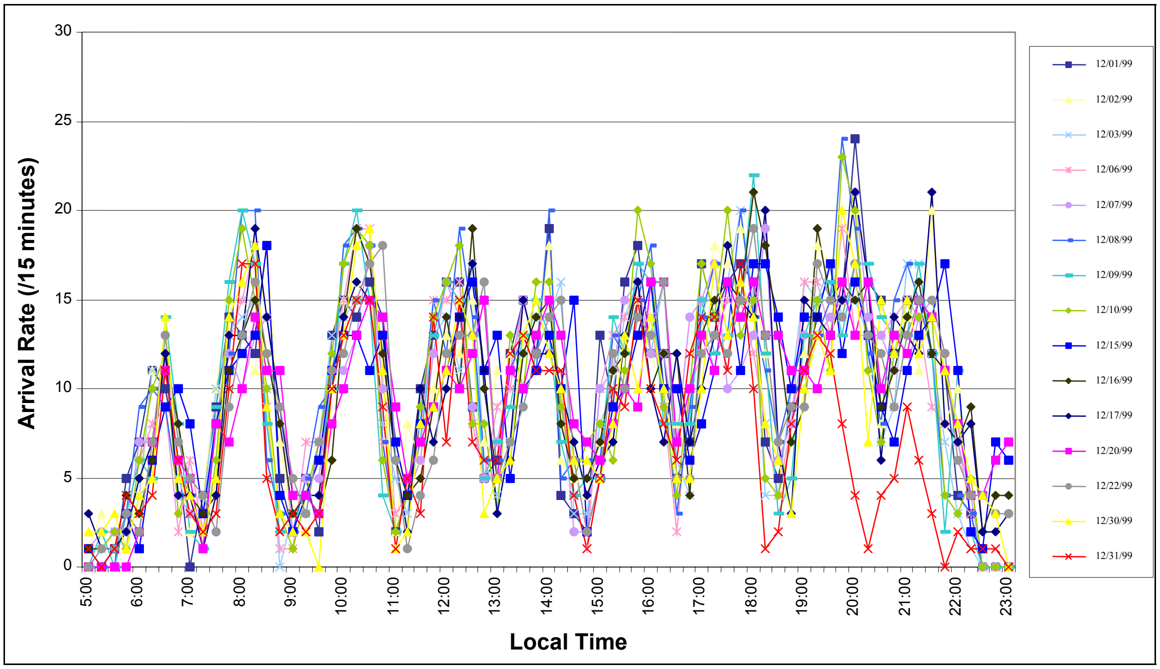

Figure 23. MSP Arrival Rates, December 1999

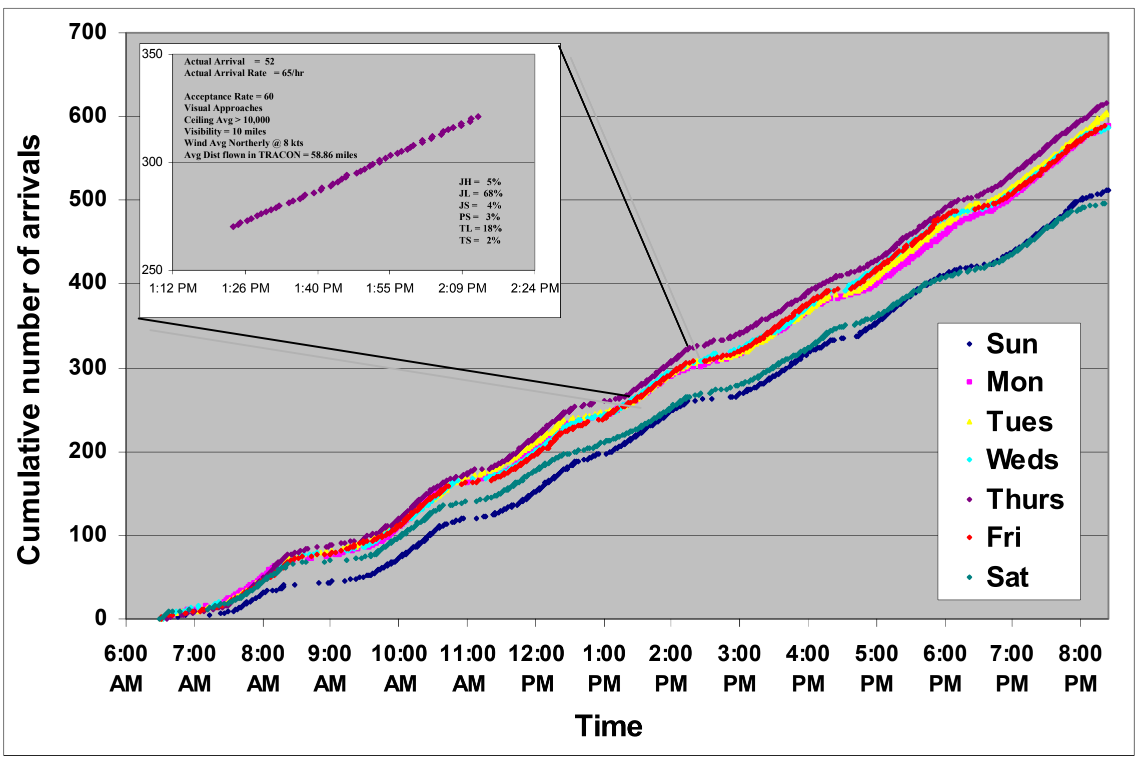

Figure 24. MSP Cumulative Arrivals, March 12-18 2000

The inset of Figure 24 "zooms in" on one rush period, which is indicated by a steep slope on the cumulative arrival curve. We have developed a methodology and associated computer software for identifying these rush periods, since these periods will provide the most fruitful data with which to analyze the performance of FFP1 capabilities (the capabilities can make little improvement in NAS performance during slack periods). This algorithm steps through aircraft arrival times, calculating “spot” arrival rates for a user-specified number of consecutive arrivals. If a sufficient number of consecutive spot arrival rates exceed the day’s overall average arrival rates, the period being examined is considered to be a rush (a minimum time period, also specified by the user, must be exceeded for the period to register as a rush). The start and stop times of the rush periods may then be used to select records from the Oracle database for further analysis.

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9.0 GLOSSARY

AAL	American Airlines
AAR	Airport Acceptance Rates
ALR	Airport Landing Rates
AM	Amendment
AOC	Airline Operations Center
ART	Analysis of Restrictions Tool
ARTS	Automated Radar Terminal System
ARTCC	Air Route Traffic Control Center
ASP	Arrival Sequencing Program
ATC	Air Traffic Control
ATCSCC	Air Traffic Control System Command Center
ATL	Atlanta Hartsfield airport
AWE	America West
BNA	Nashville International Airport
CAASD	Center for Advanced Aviation System Development
CARJ	Canadair Regional Jet
CCB	Configuration Control Board
CHI	Computer Human Interface
CODAS	Consolidated Operations and Delay Analysis System
CR	Collaborative Routing
CTAS	Center TRACON Automation System
CVG	Cincinnati International Airport
DLOG	URET DU recorded data
DR	Discrepancy Report
DSR	Display System Replacement
DSS	Decision Support System
DU	Daily Use
EDCT	Estimated Departure Clearance Time
ETMS	Enhanced Traffic Management System
ETT	Estimated Time to Touchdown
EWR	Newark
FAA	Federal Aviation Administration
FADE	FAA's Airline Data Exchange
FFP1	Free Flight Phase 1
FL	Flight Level
FSM	Flight Schedule Monitor
GAL	Gallon
GDP	Ground Delay Program
GDP-E	Ground Delay Program Enhancements
GPD	Graphic Plan Display
HID	Host Interface Device
IDU	Initial Daily Use
IFR	Instrument Flight Rules
IPE	Integrated Predictive Error

LB	Pound
MEP	Midwest Express
MIT	Miles-in-Trail
MSP	Minneapolis/St. Paul
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NASSI	National Air Space Status Information
NATCA	National Air Traffic Controllers Association
NCDC	National Climactic Data Center
Nmi	Nautical mile
NRP	North American Route Program
NWA	Northwest Airlines
OAG	Official Airline Guide
PCA	Planned Capability Available
pFAST	Passive Final Approach Spacing Tool
P-GUI	Planview Graphical User Interface
RBS	Ration-by-Schedule
RCI	Rate Control Index
RJ	Regional Jet
RUC	Rapid Update Cycle
SFO	San Francisco
SDF	Louisville International Airport
SMA	Surface Movement Advisor
SOC	Systems Operation Center
SUA	Special Use Airspace
T-GUI	Timeline Graphical User Interface
TMA	Traffic Management Advisor
TMU	Traffic Management Unit
TOC	Top of Climb
TOD	Top of Descent
TPs	Trial Plans
TRACON	Terminal Radar Approach Control Facility
URET	User Request Evaluation Tool
VFR	Visual Flight Rules
ZID	Indianapolis Center
ZME	Memphis Center

10.0APPENDIX A. LETTER TO FAA ADMINISTRATOR FROM NW AIRLINES

NORTHWEST
AIRLINES

John S. Kern
Vice President, Regulatory Compliance
and Chief Safety Officer

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February 5, 1999

Jane F. Garvey
Administrator, ADA-1
Federal Aviation Administration
800 Independence Avenue SW
Washington, DC 20591

Dear Ms. Garvey:

I want to take this opportunity to pass along our congratulations and appreciation for commissioning the first deliverable of Free Flight Phase 1 (FFP1.) The capabilities and functions as described in FFP1 of SMA for Detroit (DTW) occurred on December 30, 1998. This proof of concept has already started providing benefits to us as real time data is now available in our Systems Operation Center (SOC.) Among other things, we expect more efficient coordination and management of ground support by Northwest Airlines personnel. This is a great example of an opportunity to enhance system efficiency by sharing information that is critical to all parties in the National Airspace System.

Please also pass along our thanks to Chadie Keegan, Program Director of Free Flight and his staff for their efforts in reaching this milestone. They accomplished this task during the week of 1998 when most people were enjoying the holidays.

The FAA/Industry partnership is producing results and Northwest is pleased to be involved. We look forward to expanding that relationship and to continuing our efforts for a more efficient National Airspace System.

Best regards,

John S. Kern

JSK/lb

cc: John Dasburg
Richard Anderson
Ben Hirst

WORLDWIDE KLM NORTHWEST RELIABILITY