ASD-400 Independent Benefits Assessment

of the Free Flight Phase 2 Program

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FOREWORD

This section summarizes the results of ASD-400's independent benefit assessment of the Free Flight Phase 2 (FFP2) program. The program consists of three sub-programs:

1) User Request Evaluation Tool (URET)
2) Traffic Management Advisor – Single Center (TMA-SC)
3) Collaborative Decision Making (CDM) with the benefits associated with the Collaborative Routing Coordination Tool (CRCT) component

The evaluation of the sub-programs involved two parts: 1) the development of a range of validations using various methodologies, and 2) a review of the program office's (AOZ-30) benefit estimates that are used in the Acquisition Program Baseline (APB) and the Investment Analysis Report (IAR). The two predominant FFP2 tools TMA and URET, which account for approximately 85 percent of the FFP2 life cycle program costs, have existing FFP1 installations, e.g., TMA at Minneapolis - ZMP and URET at Memphis Air Route Traffic Control Center (ARTCC) (hereafter referred to as Centers). Using several well-accepted data sources, the ASD-400 Independent Evaluation Team's (IET) evaluation of these programs involved a range of analyses before and after daily usage. Additionally, we examined the theoretical "upper bound" benefits pool available to the URET based on perfect efficiency (routing) of qualifying flights. The methodologies and findings are described in more detail in the subsequent sections.

In summary, the overall findings of the ASD-400 IETs evaluation are inconclusive. The IET acknowledges that the Free Flight Office is the first FAA organization to measure *program metrics* in a day-to-day operational environment. While the IETs evaluation suggests that collectively the tools shows potential to improve the overall flight performance (achievable benefits) in the NAS, at this time our independent assessment is unable to support and quantify some of the claimed improvements driving the monetized benefits associated with these sub-programs. We recognize it will take additional evaluation periods to understand the true impact of an investment such as URET. ASD-400 feels that until there is more solid evidence (through the operational data at FFP1 sites) of improved flight times and/or reduced fuel usage, a moderate risk of successfully attaining both near- and long-term benefits for each of the three tools remains. Brief discussions of our findings on each sub-program follow.

URET

The available benefits from flying additional user-preferred routes (direct and/or optimized) appear to be sufficient to include the claimed URET benefits. We support the 0.52 nautical mile (nmi)/flight center (all flights that pass through a URET-equipped Center) distance savings as a reasonable and conservative metric. We do not feel, however, that using distance savings from the increased number of lateral amendments is the best performance measure - timesavings and/or fuel burn savings are much better measures. This is an important distinction because distance savings from increased lateral amendments represent approximately 95-97 percent of URET's projected monetized life cycle benefits. Moreover, attaining benefits when lifting restrictions, URET's other quantified benefit, has considerable risk of occurring in a timely manner.

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In the "bottoms-up" approach, the average airborne times were estimated for flights that pass through the two Centers (Indianapolis - ZID and ZME) that have been using URET for a significant time period. Many city pairs showed both increasing and decreasing flight times. When 28 origin-destination (O-D) pairs were examined, the results showed a small overall decrease in the airborne time variability. This implies that URET may enable slightly better predictability. However, examination of a larger set of 400 airport O-D pairs that have a significant number of flights through these two Centers yielded a small overall increase (relative to the National Airspace System (NAS)) in flight times and variance. Neither set of results has statistical significance. Overall, the results of these analyses were inconclusive.

TMA-SC

The projected benefits developed by the product team are overstated. The benefits are being generated by a mathematical simulation model, which needs additional sensitivity analysis and better future demand scheduling, to provide more reasonable projections. The application of the detailed Automated Radar Terminal System (ARTS) data from Los Angeles International Airport (LAX) to develop the actual arrival rate during peak times is the most appropriate method. This arrival rate improvement, which is developed using sufficient statistical techniques, is the dominant parameter in the model. The same peak arrival rate factor, as well as increased departure rates are applied to the four impacted FFP2 airports, i.e., Houston Intercontinental Airport (IAH), Cincinnati International Airport (CVG), Memphis International Airport (MEM), and St. Louis International Airport (STL), to provide the projected benefits. Not conducting sensitivity analysis based on patterns observed at deployed FFP1 sites presents a significant risk to the benefit projections.

TMA-SC has been in Planned Capability Achieved (PCA) status at ZMP since December 2000. At ZMP it is being used as a time-metering tool; the mode of operation that is projected to provide the maximum benefits. At this time, however, despite overall demand remaining virtually identical in the pre and post-TMA periods, our analysis reveals that there is minimal evidence of reduced airborne times or delays during peak arrival times at Minneapolis-St. Paul International Airport (MSP). As the program moves forward it is important that AOZ continues tracking relevant metrics when evaluating the performance/benefits at each site. Several of these metrics have been identified with corresponding outcome categories (predictability, flexibility, delay/efficiency, etc) in the FFP2 Integrated Program Management Plan, dated June 12, 2002 and the OEP Metrics Plan (Pre-Coordination Draft, June 2002). These metrics include enroute times, arrival delays, fuel usage and so forth.

CDM-CRCT

Very limited data from the evaluation of the Kansas City (ZKC) and Indianapolis (ZID) CRCT prototype sites are available to support the claimed benefits. The approach to identifying and developing the benefits appears reasonable. ASD-400 feels that with full collaboration from all the participants, this tool has excellent potential, but several ongoing activities must come together before it will be operable as it is planned. AOZ needs to work with the CDM program office to collect and analyze the relevant operational data to develop their identified metrics

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(impact on cancellations, diversions, flight time, departure delay in severe weather, and flight distance in non-severe weather) that can be adequately measured and supported.

Section 3.0 of this assessment documents ASD-400's comments on the draft IAR and the Basis of Estimate (BOE) section submitted by the FFP2 program office. Specifically, ASD-400's review addresses AOZ's assessment of benefits that are expected to be realized from the usage of URET, TMA-SC, and CDM-CRCT.

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1.0 INTRODUCTION

1.1 Purpose

The purpose of the ASD-400 Independent Benefits Assessment is to present an objective view of the tools planned for Free Flight Phase 2 (FFP2). This benefits assessment is one of the three components (the two other components are the cost and risk assessments) of the overall Independent Assessment Report that will be provided as part of the ASD-400 deliverable in support of the Joint Resources Council (JRC) -2B investment decision.

1.2 Objectives and Scope

There are three objectives of this independent assessment: 1) develop and estimate a high-level potential flight efficiency "benefits pool", 2) examine flight performance before and after deployment of the User Request Evaluation Tool (URET) and Traffic Management Advisor – Single Center (TMA-SC), and 3) review and provide comments on the Investment Analysis Report (IAR) submitted by AOZ. In the IAR, benefits of three tools (i.e., URET, Collaborative Decision Making (CDM)/Collaborative Routing Coordination Tool (CRCT), and TMA-SC) are evaluated.

In April 2002, TMA-SC was put back into the program baseline after it was removed from the FFP2 implementation plan in March 2002. The benefits of the Controller-Pilot Data Link Communications (CPDLC) program, which is going to a JRC as a separate program but eventually merged into the FFP2 program, will not be addressed in this assessment. Also, the FFP2 Research and Development (R&D) tools will not be evaluated. At this time, it is premature to measure the tools, TMA-Multi-Center, Direct 2, PARR, and the Surface Management System, since they are currently in concept development. Safety and productivity are not addressed in the IAR; therefore, they are not addressed in this assessment.

At the time of this report, the URET Core Capability Limited Deployment (CCLD) is operational at six Air Route Traffic Control Centers (ARTCCs)--hereafter referred to as Centers: Indianapolis Center (ZID), Memphis Center (ZME), Kansas City Center (ZKC), Washington Center (ZDC), Cleveland Center (ZOB) and Chicago Center (ZAU). Currently, the CRCT tool is being prototyped at the Air Traffic Control System Command Center (ATCSCC) and the ZKC and ZID Centers. URET FFP2 implementation is scheduled for 13 Centers, with the next site scheduled to begin in early 2003 and completion scheduled by the end of CY05; CRCT deployment is scheduled between June 2002 and 2005 at all 20 Centers. Recently, TMA-SC has gone into Planned Capability Achieved (PCA) status at the following FFP1 sites: Miami Center, Denver Center, and Minneapolis Center; and Initial Daily Use (IDU) status at Oakland Center, Atlanta Center, and Los Angeles Center.

This assessment is divided into two sections: 1) an evaluation of FFP2 tools, i.e., URET, TMA-SC, and CDM-CRCT, and 2) comments on the draft IAR provided by AOZ.

2.0 ASD-400 INDEPENDENT ANALYSIS

This section covers the *top-down approach*, which has the intention of providing two pieces of information: 1) validate if the pool of available benefits that the product team is claiming is reasonable, and 2) estimate the potential fuel burn savings in the National Airspace System (NAS) for which URET may provide an enabling function for the achievement of further efficiency gains when combined with other programs (e.g., En Route Automation Modernization (ERAM), Wide Area Augmentation System (WAAS), CPDLC, and NEXCOM). The allocation of these potential benefits are <u>not</u> included or estimated in this analysis.

The *top-down approach* entails modeling multiple days while maintaining consistency with the primary capabilities that are depicted in the Operational Evolution Plan (OEP) and the NAS Architecture. In the analysis, with the goal to substantiate the reported contribution of URET, it assumed that other initiatives *not directly dependent* on URET executability would also be able to claim a portion of the "benefits pool". These initiatives include the establishment and certification of further area Navigation (RNAV) routing, the enhancements of the ongoing North American Route Program (NRP), procedural changes, and increased equipage. Furthermore, expected flight efficiency benefits of forthcoming large capital FAA investments such as the ERAM, WAAS, CPDLC, and NEXCOM are not addressed in this report, but need to be considered within the domain of developing a flight efficiency benefits pool.

The other method of analysis, a *bottoms-up approach,* consists of various analyses that attempt to measure URET's impact on flight performance (en route flight time) when used in the Memphis (ZME) and Indianapolis (ZID) Centers and before implementation at those facilities, i.e., a pre- and post-implementation assessment. Comparisons in flight performance relative to the flights through these two Centers between the other Centers where URET has not been deployed (as of spring-2002) are made. Similarly, the flight performance of TMA-SC is evaluated multiple ways through data analysis and modeling from a pre and post-implementation perspective[1].

In Section 3.0 of this assessment, ASD-400 comments on the draft AIR, primarily the Basis of Estimate (BOE) section. Specifically, ASD-400's review addresses AOZ's benefits assessment of URET, TMA-SC, and CDM-CRCT functionalities.

2.1 Benefits' Models, Tools, and Data Sources

The ASD-400 study team (comprised of ASD-400 and SETA-II contract support) used several models, tools, and data sources for the analyses to determine if the benefit claims are reasonable and supportable. The primary ones are listed in Table 2-1.

[1] This analysis concentrates on flight timesavings and fuel savings, not distance savings. Time saved provides a direct benefit to the user community; distance saved may not directly translate into time saved due to contrary winds or downstream impacts.

Table 2-1: Models, Tools, and Data Sources

Models/Tools and Primary Databases	Key Function	Top-Down	Bottoms-Up
Find Crossings	Computes the time and location when an aircraft enters and leaves a sector. This tool also can be used to calculate counts of aircraft in a sector for a given time.	X	
NAS Performance Analysis Capability (NASPAC)	A discrete-event simulation model that evaluates the NAS based on capacity/demand relationships. Gives operational delay in this analysis.	X	
Optimal Trajectory Generator (OPGEN)	Computes optimized flight trajectories (direct or wind optimized) based on winds aloft observations.	X	
Total Traffic Tool	Identifies proximity alerts between pairs of aircraft based on horizontal and vertical user-specified separation criteria.	X	
Enhanced Traffic Management System (ETMS)	IFR flight plans that are either "as flown" or "as filed." Trajectories can be built for each flight.	X	X
ETMS Visualization Tool	Merges the various ETMS message types into a consolidated format suitable for OPGEN.	X	X
Future Demand Generator	Projects future flights based on ETMS data and the TAF projections.	X	X
Air Traffic Operations Network (OPSNET)	Official air traffic delay database. Captures all reportable delays exceeding 15 minutes. Reports delays by type (i.e., departure, arrival, en route) and cause (i.e., weather, traffic flow, equipment, etc).		X
Airline Service Performance Metrics (ASPM)	Airborne times and filed-estimated time en route (ETE) for all filed-IFR flight plans (2001 to present) that are flown.		X
Airline Service Quality Performance (ASQP)	Airborne times, ground times, and delays for 10-12 major carriers submitted monthly to the Department of Transportation. It is used for on-time performance reporting.		X
Airport Capacity Tool	Current and future capacities Instrument Flight Rules (IFR) and Visual Flight Rules (VFR) capacities from the busiest airports (based on 2000 Airport Capacity Survey and FAA Benchmark Study).		X
Consolidated Operations and Delay Analysis System (CODAS)	Same information as ASPM, but has 1998-2000 data. Airborne times and filed-estimated time en route (ETE) for all filed-IFR flight plans that are flown.		X
National Climatic Data Center (NCDC) Surface Weather	Hourly surface data that gives ceiling, visibility, and winds by airport.		X
Post Operations Evaluation Tool (POET)	Provides detailed flight plan information (includes sectors flown and amendments).		X
Terminal Area Forecast (TAF)	Historical, current, and forecast data for enplanements, operations, and instrument operations for the majority of the airports in the NAS.		X
Wind Profiles	Winds aloft grid data in the upper atmospheres required for OPGEN runs. Winds are based on forecasted observations every 6 to 12 hours.	.	X

In the bottoms-up approach, various combinations of data from 1995 to 2001 were evaluated. In the top-down approach, the current years as well as future years were applied.

2.2 URET Top-Down Approach

The purpose of this approach is to independently estimate an upper bound of available benefits that are attributable to URET and other programs. The benefits claimed by the URET product team should not exceed those provided by this estimate.

2.2.1 Ground Rules and Assumptions

Several ground rules and assumptions were applied in the top-down approach. The primary assumptions are presented in the following categories: Time, Routes, Airspace, Fuel Burn, and Equipage/Aircraft.

Time

- Eight modeling days were used for the 2001 baseline. These days consist of two very good, two below average, and four average performance days.
- Two flight profiles, a 2001 baseline and 2005 future profile, with incremental improvements are assessed.
- Traffic forecasts are derived from both the Federal Aviation Administration Office of Aviation Policy and Plans (FAA/APO) Terminal Area Forecast (TAF) for the terminal demand and the airspace forecasts. This information, combined with the Boeing fleet forecast, was used to develop the 2005 scenario.

Routes

- The 2001 baseline scenario uses the Enhanced Traffic Management System (ETMS) data to look at the flights as they actually flew. By default, this scenario reflects the current use of RNAV and NRP routes and other initiatives currently in place.
- Routes are dependent on climb and descent profiles by one of the assigned aircraft categories. Routes are comprised of either wind-optimized routes or user-preferred routes, i.e., direct routes or ATC-preferred routes.
- Aircraft that were RNAV-equipped and met certain other criteria were provided with wind-optimized routes. The National Oceanic and Aeronautic Administration (NOAA)/UCAR-gridded wind data for the day was used, and the routes were generated using OPGEN. Only those aircraft that flew at or above FL240 and had a minimum stage length of 500 nautical miles (nmi) were considered candidates for optimization. In order to eliminate the effects of the terminal area, only that segment of flight at or above FL240 beyond 200 nmi from the departure or arrival airport was optimized.
- All optimized routes abide by Special Use Airspace (SUA) restrictions. Whenever possible, optimized routes are flown; however, where there is an active SUA in the flight path, an optimized flight is generated that avoids the region.

Airspace

- The sector capacities, the Monitor Alert Parameters (MAPs) threshold, of the low, high, and super-high sectors are provided by the ATCSCC. These capacities represent a theoretical maximum number of aircraft that can be accepted in a sector at a given time. The sectors and the MAPs are assumed to remain constant for the 2005 scenario.
- Sector boundaries, which currently are being evaluated through the National Airspace Redesign (NAR), were not adjusted in the 2005 scenario. Sufficient information was not available at the time of the analysis
- The daily number of proximity alerts (conflicts) and instantaneous Center counts are used to identify areas where conflict resolution automation would be required.

Fuel burn

- In this analysis, OPGEN computes the fuel burn rate in the airborne phase (cruise over FL240) of the flight. Aircraft type, speed, flight level, and weight (estimated by varying the load factor for eligible flights from .59 to .77) impact the rate. The combinations of these variables are computed between waypoints.

Equipage/Aircraft

- The aircraft types and equipment codes were extracted from the ETMS data for all flights.
- The future NAS initiatives, specified in the OEP, include increased RNAV equipage and certification, and domestic Reduced Vertical Separation Minimum (RVSM) for eligible aircraft that were not factored into the 2005 scenario.
- The equipage attributes of commercial, air taxi/commuter, and general aviation (GA) aircraft are defined in the ATC 7110.65 publication. This publication identifies equipage codes by carrier and aircraft type that can offer optimized routing capability through multi-sensor Flight Management System (FMS) and the equipage of Global Positioning System (GPS) receivers.
- There are 15 distinct series of aircraft, e.g., 727, which are candidates to fly optimized routes (see Appendix A, Table A-1). All eligible aircraft type that meet the criteria annotated in the next section were mapped to an aircraft type represented in OPGEN when applying OPGEN runs.

2.2.2 Methodology

The objective of this part of the assessment is to develop an upper bound of flight efficiency benefits. The methodology assumes flights that meet certain criteria (see below) can fly a wind optimized (fuel efficiency meeting pre-optimized arrival time) route. This results in significant fuel savings (not necessarily time because of fuel optimization as the highest criteria) when compared to the non-optimized "as-flown" baseline. Note that distance savings is *not* an optimization criteria.

The following criteria were applied to the flights to determine the candidates for optimization:

- Altitude >=FL240
- Stage length >=500 nmi in CONUS
- Aircraft type mapped to one of OPGEN aircraft
- RNAV aircraft equipage (see Table 2-2)

The ETMS data contained the aircraft type and equipment identifier for each flight. Only those aircraft with the following codes were considered for optimization.

Table 2-2: Aircraft Equipage Codes and Definitions

Equipment Code	Definition
/Y	LORAN, VOR/DME, or INS with no Transponder
/C	LORAN, VOR/DME, or INS, Transponder with no Mode C
/I	LORAN, VOR/DME, or INS, Transponder with Mode C
/E	FMS) with en route, terminal, and approach capability. Equipment requirements are: Dual FMS, which meets the specifications of AC 25-15, Approval of FMSs in Transport Category Airplanes; AC 20-129, Airworthiness Approval of Vertical Navigation (VNAV) Systems for use in the U.S. NAS and Alaska; AC 20-130A, Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors; or equivalent criteria as approved by Flight Standards. A flight director and autopilot control system capable of following the lateral and vertical FMS flight path. At least dual inertial reference units (IRUs). A database containing the waypoints and speed/altitude constraints for the route and/or procedure to be flown that is automatically loaded into the FMS flight plan. An electronic map. (U.S. and U.S. territories only unless otherwise authorized.)
/F	A single FMS with en route, terminal, and approach capability that meets the requirements of /E, 1-4 above (i.e., U.S. and U.S. territories only unless otherwise authorized).
/G	GPS/Global Navigation Satellite System (GNSS)-equipped aircraft with en route, terminal, and GPS approach capability.
/R	Required Navigational Performance. (Denotes capability to operate in RNP designated airspace and routes.)

By restricting the flights to be optimized to those with the equipment codes above, this estimate of the pool of benefits is conservative. Non-RNAV-equipped aircraft are also capable of flying an optimized route by receiving vectors from air traffic controllers. This would require significantly higher controller workload, however, and it did not seem reasonable to assume that every non-RNAV-equipped aircraft would be able to realize the benefit of the wind-optimized routing.

Eight days in 2001 were selected to provide a good representation of the year (See Table 2-3). For example, March 15, 2001, represents a poor performing day (ranked number 30 in the month) with a very high airborne time (about 1.5 minutes over average) and 22 percent of the flights arriving 30 minutes past the scheduled arrival time. Conversely, August 29, 2001, represents a very good performing day (ranked number 2 in the month) with a lower average airborne time (about 2 minutes less) and only 6 percent of the flights arriving 30 minutes past the scheduled arrival time.

Table 2-3: Modeled Days Through OPGEN

2001 Date	Ranking (within month)	Delay > 30 Min.	Average Airborne	Average Block Time	Block Time Met (%)
0315	30	22%	104.7	128.2	57%
0419	13	7%	102.3	123.6	66%
0517	25	11%	102.6	125.3	65%
0614	29	24%	105.5	131.9	54%
0821	6	8%	103.6	125.5	69%
0828	14	12%	103.4	126.7	67%
0829	2	6%	102.8	125.4	68%
0905	17	7%	101.8	124.4	69%

2.2.3 Findings

Across all of the days, the median flight saved 889 pounds of fuel. The median stage length of the qualifying flights was 850 nmi. On the good performance days, the median flight saved 840 pounds of fuel; and on the poor performance days, the median flight saved 999 pounds of fuel. This indicates that there is a greater potential for savings on poor performance days; therefore, restricting the pool of benefits to good performance days can be considered conservative. Looking at the mean percentage of *fuel saved per qualifying flight* shows a similar trend with 10 percent fuel saved on good performance days, 11 percent fuel saved over all days, and 12% fuel saved on poor performance days. It is important to note that these fuel savings are only for the aircraft that met the criteria for flying optimized routes (see Appendix A, Table A-1). It is expected that the fuel savings realized by most other aircraft types would be significantly less, due to the typically shorter routes and small fuel burn rate.

It is assumed that the aircraft capable of flying wind-optimized trajectories, flying larger transport aircraft, will realize the greatest benefit. In order to eliminate the effects of outliers, the median fuel savings of 840 pounds (the good day median - selected for consistency with Free Flight Program Office) can be multiplied by the 7,200 qualifying flights on average per day that were candidates for optimization, arriving at a daily pool of six million pounds (900,000 gallons) of fuel to be saved. This assumes that all facilities have URET, that all eligible flights are able to fly their optimized routes, and that all restrictions beyond 200 nmi of the origin and destination airports have been eliminated. This method has the advantage of eliminating the possibility of “double-counting” benefits for advances in airspace efficiency already in use. Since ETMS data was used, the benefit calculated by optimizing the eligible flights illustrates the current inefficiencies in the NAS. The effects of existing NRP and RNAV routes that have already been implemented were captured before the flights were optimized, although this does not take into account future increases in the use of these routes, especially RNAV routing.

To translate the daily savings to an annual value, it is assumed that the savings from other aircraft will be negligible. Adjusting for the lower demand on weekends (~85 percent of weekdays) the total annual fuel usage would roughly be 310 million gallons at $0.67/gallon or $210M of annual saving if <u>all</u> the NAS inefficiency beyond 200 nmi of origins and destinations of the airport could be eliminated. In addition, by basing the benefits pool on the good performance days, this estimate is conservative relative to the total potential pool of NAS efficiency benefits. As illustrated in the above paragraph, the poor performance days had a 19 percent greater opportunity for benefit than the good performance days. On average, this metric is likely to be conservative by 6 percent.

To assess the impact of enabling the qualifying flights to fly wind optimized routes an analysis of the maximum instantaneous sector counts was performed. Find Crossings was used to count the number of aircraft in every sector every 15 minutes. These results were then compared to the published MAP threshold values. Figure 2-1 shows the sectors for the airspace at and above FL240 (high and super-high) that would incur traffic at levels higher than the published MAP[2]. The colors represent the number of aircraft above the MAP level.

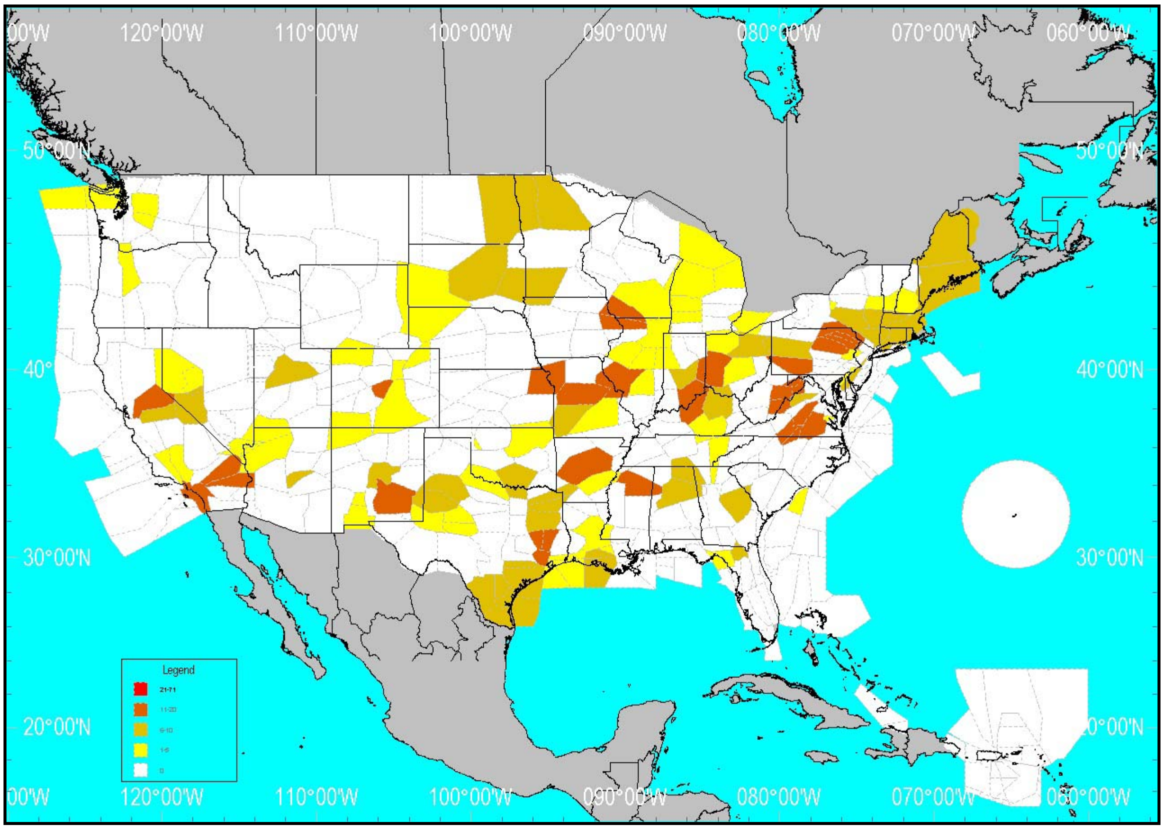

Figure 2-1: 2001 Sectors Exceeding MAP

From Figure 2-1, it is apparent that the airspace providing the transition to the busiest airports becomes saturated. In addition, sectors in the vicinity of frequently active SUA also becomes congested, because the optimized flights fly the most economical route to meet a schedule, while meeting current SUA constraints. Additional automation (in the form of URET and other tools) may allow air traffic specialists to handle the increased demand in these sectors.

The reported benefit of URET is the ability to assist the controller in separating aircraft from aircraft and not aircraft from airspace. The highlighted sectors above indicate where aircraft would be separated from airspace.

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[2] The darkest shade reveals 21-70 aircraft that exceeded the MAP threshold; second darkest shade reveals 11-20 aircraft that exceeded the MAP threshold; third darkest shade reveals 6-10 aircraft that exceeded the MAP threshold; and so forth.

The Future Demand Generator (FDG) was used to develop a scenario for 2005. Again, OPGEN was used to optimize eligible flights beyond 200 nmi of their origin and destination airports. The current sectorization was assumed, and equipage was not adjusted. Find Crossings was run to calculate the maximum instantaneous aircraft counts for each sector.

Figure 2-2 illustrates that by 2005 significantly more sectors would exceed the 2001 MAP levels.

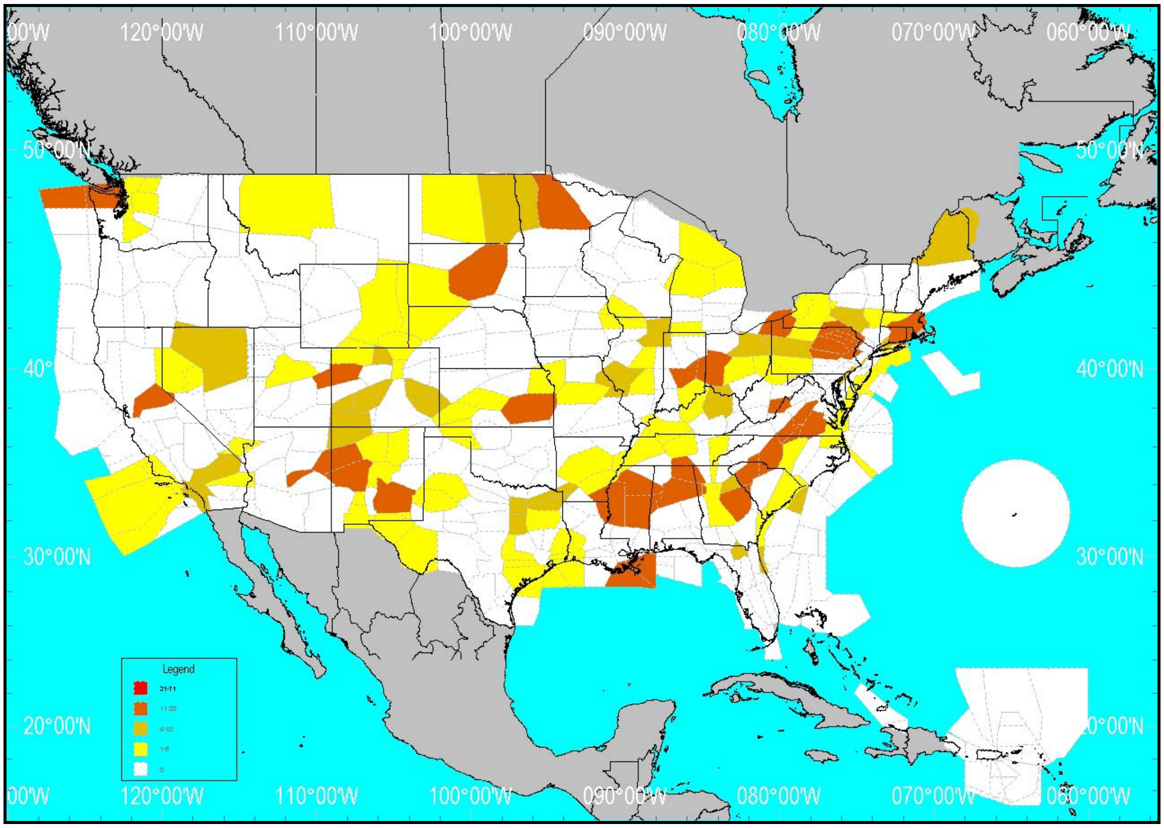

Figure 2-2: 2005 Sectors Exceeding MAP

Table 2-4 below shows the maximum number of aircraft in each Center in 2001 and 2005. The saturation extends beyond the transition sectors to more of the en route environment. Without automation, this likely would lead to additional procedural separation restrictions being imposed.

Table 2-4: Maximum Aircraft by Center

ARTCC	# of Sectors Exceeding MAP (2001)	Max Instantaneous Aircraft in 2001	Max Instantaneous Aircraft in 2005
ZAB	2	482	562
ZAU	5	649	829
ZBW	2	331	482
ZDC	0	542	731
ZDV	3	457	494
ZFW	1	586	763
ZHU	0	655	911
ZID	9	615	811
ZJX	2	331	462
ZKC	2	650	845
ZLA	6	557	673
ZLC	0	268	311
ZMA	1	212	315
ZME	2	483	566
ZMP	1	511	587
ZNY	1	324	446
ZOA	2	358	482
ZOB	8	600	803
ZSE	0	182	303
ZTL	2	630	1070

2.3 URET Bottoms-up Approach

This part of the assessment compares the airborne times of flights between city pairs that flew through either ZME or ZID Centers or both before and after two-way inter-facility communications capability was instituted in July 1999.

Three bottoms-up evaluations were performed to validate the claimed URET distance savings. In the first evaluation, a limited set of city pairs (origin-destination) was included. By examining both the ETMS data and the POET, city pairs were identified and analyzed. ETMS provided the initial list of flights that crossed either ZME or ZID. Selected flights were then analyzed with POET to eliminate flights that only occasionally crossed one of the Centers. This method provided a list of 28 city pairs that routinely cross the Centers for a significant length of time during their flight. The second evaluation examined the "excess distance" by comparing the mean flight distance with the great circle distance. It was expected that this would provide an *upper bound* to the URET benefits. The third evaluation evaluated flights that crossed the region for at least 10 minutes several times a day based on the ETMS data developed using the ETMS Visualization Tool (EVT); 400 city pairs met this criterion. It was expected that the flight performance from this set of flights would provide a *lower bound* for the URET benefits. In each of the evaluations, Airline Service Quality Performance (ASQP) data was used to determine airborne times and the estimated benefits.

2.3.1 Airborne Time Evaluation of 28 City Pairs

This part of the assessment compares the airborne times of flights between city pairs that flew through the Memphis and Indianapolis Centers (ZME and ZID), respectively or both before and after using the URET prototype. Data through the ETMS reveals that several thousand-city pairs that are represented spend at least 5 minutes over ZME or ZID. For this analysis, we initially selected 34 city pairs randomly from flights that almost always flew over one of the Centers. POET was used to plot one month of flights from these 34 city pairs. Plotting revealed that 28 of the city pairs consistently had flight paths over ZME or ZID. The remaining six city pairs had significant numbers of flights that did not pass through these two Centers and were eliminated from the analysis. Table 2-5 presents the findings on flight paths using POET for the 28 city pairs evaluated.

Table 2-5: 28 Key City Pairs Evaluated

Departure	Arrival	Notes
ATL	CVG	ZID only
ATL	DAY	ZID only (landing in ZID)
ATL	DEN	ZME most of the time
ATL	MCI	ZME
ATL	MSP	ZME or ZID (each half time)
ATL	ORD	Both Centers
ATL	PIT	ZID only
BWI	MDW	ZID most of the time
CMH	ORD	ZID only
DEN	IAD	ZID only
DTW	CVG	Airport Inside ZID
DTW	MEM	Both Centers, lands in ZME
IAH	DTW	Both Centers
IND	STL	ZID only
LAX	IAD	ZID and sometimes ZME
LGA	DFW	Both Centers
MDW	CMH	ZID only
MEM	ATL	ZME only (starts in the Center)
ORD	ATL	Both Centers
ORD	CLT	ZID only
ORD	IAH	Mostly through ZME
ORD	MCO	ZID only
ORD	MIA	ZID only
SDF	STL	ZID (airports in ZID)
STL	CLE	ZID to the north of Center
STL	DCA	ZID
STL	IND	ZID only (landing in ZID)
STL	LIT	Landing in ZME only

2.3.1.1 Methodology

We started by collecting airborne times from 1995 to 2000 between all flights from the 28 city pairs. The airborne times from the ASQP data were used (see description in Section 2.3.1.2). Next, using SPSS, frequency distributions were calculated for each city pair's airborne time.

Detailed results for each city pair are available upon request. For a given city pair, airborne times that flew through ZME and/or ZID were compared for each timeframe. The two timeframes compared are as follows:

- Pre-URET — comparison of airborne performance of 1995 frequency distributions to 1998.
- Post-URET — comparison of airborne performance of 1998 frequency distributions to 2000.

These comparisons show the trends of airborne time distributions after having URET at the Centers when the two-way host interface was implemented. We call these the post-URET airborne time comparisons.

There are different cases that can be observed. One case is when a median airborne time increased by 2 minutes between 1995 and 1998, but only increased .5 minutes between 1998 and 2000. One can conclude that having URET might have contributed to the declining rate of airborne time increase. Another case is when the mean and median remained the same but the standard deviation fell between 1998 and 2000 when it had an increasing trend prior to 1999, then one can conclude that URET may have contributed to a tighter airborne distribution. Predictability metrics may be hard to assign an economic value, but since they are important for airlines, they must impact their bottom line. Improved airborne time predictability for a city pair may enable the airlines to reduce their scheduled block times. Thus, a tighter airborne time distribution can be assigned an economic value by reduction in block times. In Section 2.3.1.3, we discuss changes in scheduled block times for DTW-MEM where the standard deviation has fallen between 1998 and 2000. Conversely, the opposite effect takes place when the airborne times and standard deviations increase.

In a previous ASD-400 study[3], a first cut was established to measure changes in airborne distributions for nine airports between 1995 and 2000. When the destination airport of our 28 city pairs were one of the nine airports in that study, we further compared post-URET airborne time comparisons to the results found in the study. This again shows how this city pair performed compared to other city pairs flying into the same airport. Again, if the statistics of the selected city pair were better than the ones found in study, then one could hypothesize that URET had a positive effect on reducing the increasing airborne time trends. It has been hard to show any significant differences looking at airborne averages for the entire city pairs' population and those that fly over ZME and ZID. For this reason, we concentrated on entire distributions not just averages. Lastly, we should observe that any improvement might be due to factors other than URET.

2.3.1.2 Data Collection

The ASQP data between 1995 and 2000 was used in this analysis. The ASQP database provides source, destination, flight time, scheduled, and actual flight and airborne times as well as taxi-in and taxi-out times. Aircraft speed varies by aircraft type. Propeller aircraft (turboprops and

[3] Nastaran Coleman, "Optimized Flight Time", September 2001.

piston-engine) fly slower at speeds than jets. However, for the 28 city pairs, the annual changes in the number of propeller aircraft reported in ASQP were small enough that we did not filter them out. ASQP data alone comprise about a half million records a month or over 16,000 flights per day.

Manipulating and analyzing several years of these data is a time-consuming, difficult task; consequently, we considered sampling to ease handling of this dataset. Sampling plans include using one representative month, or 12 sample days (one day per month of the year) to capture seasonal differences. Since weather plays a significant role in the length of the airborne times, weather effects on delays must be identified and adjusted for all years. This is not an easy task, especially since our current weather information is limited to hourly surface weather. Furthermore, historical data for convective weather has not been collected for multiple years. Moreover, the effects of different weather scenarios on delay are not understood completely requiring ongoing research efforts. Thus, we decided to use all days and work with huge databases.

2.3.1.3 Results - Comparing Annual Distributions

First, we generated pre- and post-URET distributions. Pre-URET is defined by comparing 1998 airborne distributions for selected city pairs to the corresponding distributions in 1995. Post-URET is defined similarly using 2000 and 1998, respectively. Comparing all three years together for a city pair enables the evaluation of the impact of URET on that city pair.

Tables 2-6 and 2-7 provide illustrations of airborne time performance with the relevant statistics for one of the 28 city pairs - DTW to MEM. Table 2-8 shows the DTW-MEM airborne time statistics for each year. In this example, the airborne time's median, mean, and standard deviation increased by 2.0, 1.64, and .23 minutes, respectively, between 1998 and 1995 (pre-URET), but actually decreased between 2000 and 1998 (post-URET) as traffic, defined as number of aircraft handled, increased (see Table 2-9 below).

Table 2-6: Airborne Time Statistics of DTW to MEM (minutes)

Measure	1995	1998	2000
# of Flights	2569	2795	3100
Min	79	81	81
Median	89	91	90
Mean	90.6	92.2	91.7
Max	120	126.8	122.7
Std. Dev.	8.1	8.4	7.9

Table 2-7: Airborne Time Probability Bands of DTW to MEM (minutes)

Percentiles	1995	1998	2000
0.05	79.1	81.1	81.1
0.25	85.0	86.0	86.0
0.5	89	91	90
0.75	94.9	95.9	95.9
0.95	105.3	107.3	105.4

Table 2-8: DTW-MEM Airborne Time Statistics (Absolute Difference in Minutes)

Measure	Absolute Diff. (95-98)	Absolute Diff. (98-00)
Median	2.00	-1.00
Mean	1.64	-0.64
Std. Dev.	0.23	-0.54

Table 2-9: Number of Aircraft Handled by Center (000s)

ARTCC	1995	1998	2000	Chg. 95-98	Chg. 98-00	Chg. 95-00
ZME	2,003	2,144	2,232	7%	4%	11%
ZID	2,117	2,444	2,685	15%	10%	26%

Source: Administrators Fact Book, January 2002

Looking at scheduled block times for DTW and MEM illustrates how tightening of the airborne distribution impacts the airlines' scheduling. These are summarized by statistics in Tables 2-10 and 2-11. The scheduled block time follows a similar pattern to the airborne time. The median time increased by over 3 minutes between 1995 and 1998, but remained virtually the same between 1998 and 2000. Thus, one can conclude that URET might have prevented airlines from increasing their schedule block times, which in turn, may have reduced costs.

Table 2-10: DTW-MEM Scheduled Block Time Statistics

Measure	DTW-MEM		
	1995	1998	2000
Min	107	112	113
Median	116.9	120	120.1
Mean	115.9	120.8	121.2
Max	125	129.6	135.7
Std Dev.	5.1	4.5	5.1

Table 2-11: DTW-MEM Scheduled Block Time Probability Bands

Percentile	1995	1998	2000
0.05	107.1	112.2	113.2
0.25	112.1	117	116.1
0.5	116.9	120	120.1
0.75	120	124	125
0.95	123.8	127.9	129.6

As shown in Table 2-12, patterns in the airborne distributions suggest that these distributions widened between 1995 and 1998, but started tightening up in 2000. From 1998 to 2000, the standard deviations tightened in 14 of the 28 city pairs from the 1995 to 1998 difference. These are all positive signs that, despite traffic growth at several of these city pairs, the airborne time distribution is getting tighter and shifting to the left.

In this case, mean and median airborne times are increasing at a much slower rate, and the predictability case is improving (smaller standard deviation). This improvement can result from URET and/or various factors, and one can conclude that URET might have contributed to the declining rate of airborne time increase.

Table 2-12: Summary of 28 City Pairs (Standard Variations)

	Difference from 1995 to 1998					Difference from 1998 to 2000			
City Pair	Flights (in 1995)	Median (minutes)	Mean (minutes)	Std. Dev.	Flights (in 1998)	Flights (in 2000)	Median (minutes)	Mean (minutes)	Std. Dev.
ATL-CVG	3091	1	1.95	1.8	3970	3206	0	-0.62	-1.61
ATL-DAY	1475	1	0.66	1.04	1816	1794	0	0.6	-0.5
ATL-DEN	3256	0	-0.49	-0.41	3926	3515	3	3.41	0
ATL-MCI	2195	0	-0.37	-0.57	2515	2377	1	1.82	1.26
ATL-MSP	3118	-2	-1.97	-0.37	3432	3691	0	0.12	-0.33
ATL-ORD	8711	0	0.09	0.52	10120	9261	2	2.53	0.54
ATL-PIT	3920	1	0.81	0.33	3783	3182	0	-0.29	0.05
BWI-MDW	2449	0	0.19	-0.03	2820	4130	2	2.38	1.15
CMH-ORD	2137	-1	-0.78	0.8	2036	1971	2	2.02	0.07
DEN-IAD	2656	2.5	2.7	1.3	2928	3196	3.5	2.97	0.14
DTW-CVG	2527	0	0.63	0.06	1183	367	-0.94	-0.8	-0.28
DTW-MEM	2569	2	1.64	0.23	2795	3100	-1	-0.64	-0.54
IAH-DTW	1443	-1	-1.5	-1.16	1677	3298	2	2.49	1
IND-STL	4288	0.03	0.61	0.98	3785	3754	-0.03	-0.96	-1.28
LAX-IAD	3285	0	0.19	1.35	3941	4434	3	4.23	2.21
LGA-DFW	7153	-1	0.65	-0.49	6747	5916	-1	-1.8	0.89
MDW-CMH	4032	0.03	-0.18	-0.6	3663	2201	0	0.08	0.22
MEM-ATL	4813	0	0.93	0.84	4745	3718	-2	-2.55	-1.48
ORD-ATL	8369	-1	-0.18	1.76	10130	9256	0	-0.68	-1.57
ORD-CLT	3189	-0.97	-0.53	-0.53	3315	4144	1	1.04	0.47
ORD-IAH	6170	1	0.9	1.42	6128	6239	-1	0.12	0.93
ORD-MCO	4016	-1	0.14	0.73	3361	3680	1	0.69	-0.14
ORD-MIA	4486	-2	-1.99	0.74	5114	5149	1	0.39	-0.5
SDF-STL	3785	0.01	0.51	0.28	3750	3246	0	-0.62	-1.39
STL-CLE	4450	-0.94	-0.4	0.22	3287	2832	2	1.95	0.54
STL-DCA	2909	-1.03	-0.8	-0.13	2619	2356	1.09	1.46	0.38
STL-IND	4323	0.94	0.48	0.55	3821	3774	0.06	0.35	-0.36
STL-LIT	3467	0	0.51	0.47	3410	3351	-0.03	-0.62	-0.94

A similar pattern is not present, however, in several of the other 27 city pairs. Tables 2-13 and 2-14 summarize the weighted average statistics over all these city pairs. Table 2-13 details the absolute differences in minutes/seconds, while Table 2-14 shows the percent difference. The changes in mean and median airborne times are about the same for both pre-URET and post-URET. The average standard deviation of airborne time rose by 7 percent between 1995 and 1998, but stabilized and decreased slightly by .43 percent between 1998 and 2000.

Table 2-13: Weighted Average Statistics for 28 City pairs (Absolute Differences in Minutes/Seconds)

Measure	Absolute Diff. 95-98	Absolute Diff. 98-00
Median	-0.17/-10.5	0.74/44.7
Mean	0.18/11.0	0.74/44.3
Std Dev	0.59/35.2	-0.04/-2.1

Table 2-14: Weighted Average Statistics for 28 City Pairs (Percent Differences)

Measure	% Diff. 95-98	% Diff. 98-00
Median	-0.18%	0.76%
Mean	0.19%	0.75%
Std Dev	7.15%	-0.43%

This suggests that the overall airborne time distributions remained the same while traffic grew between 1998 and 2000. This is a positive improvement to which URET *might* have contributed, but it is hard to assign an economic value because it did not result in reductions in airborne times.

Finally, for city pairs arriving into DCA, DFW, and ORD, we also compared the airborne results to airborne changes at the arrival airports found in the ASD-400 study. This shows how this city pair performed compared to other city pairs flying into the same airport. If the statistics of the selected city pair were better than the ones found in ASD-400 study, then one could hypothesis that URET had a positive effect on reducing the increasing airborne time trends. We examine one example closely.

We compared all flights departing Columbus, Ohio International Airport (CMH) and arriving at ORD. From the ASD-400 study, ORD statistics are based on all arrivals into ORD. Tables 2-15 and 2-16 show the statistics for CMH-ORD and all ORD arrivals. The changes in mean and median airborne times are almost identical between CMH-ORD and all other arrivals into ORD. However, the increase in standard deviation is somewhat less, (.07 minute) for CMH-ORD, compared to all other arrivals into ORD (.93 minute). This shows a similar conclusion, as do all the other ways we look at the distribution.

Table 2-15: CMH-ORD Airborne Time Statistics
(Absolute Difference in Minutes)

Measure	Absolute Diff. 95-98	Absolute Diff. 98-00
Median	-1.00	2.00
Mean	-0.78	2.02
Std. Dev.	0.80	0.07
# of Flights	2036	1971

Table 2-16: ORD Airborne Time Statistics
(Absolute Difference in Minutes)

Measure	Absolute Diff 95-98	Absolute Diff 98-00
Median	1.60	2.00
Mean	0.40	2.20
Std. Dev.	0.79	0.95

In short, URET might have contributed to stabilizing the actual airborne time distributions, i.e., no increase in standard deviations of airborne time distributions, despite traffic growth. If this is the case, then it may have prevented airlines from increasing their block times for some city pairs flying over the ZME and ZID Centers and consequently containing their operating costs. Nevertheless, these savings are not visible when compared to other flights that flew through the rest of NAS. Therefore, it is difficult to assign an economic value to this possible improvement.

2.3.2 Examination of Flight Distance

In order to validate the claimed distance benefits associated with URET, we examined the same 28 key city pairs (see Table 2-5) as above on two good performance days in 1998 and 2001. The two good performance days in 1998 were used to construct a baseline (pre-URET) case with the 2001 data providing the post-URET comparison. The ETMS data was parsed, and the portion of the flight from beyond 200 nmi of the departure airport to 200 nmi from the arrival airport was examined. This has the effect of reducing the impact of the terminal area (holds, circles, etc.) on the results. An additional criterion that the flight reached FL240 was then applied. From this data, the mean "as flown" flight distance was compared to the great circle distance (see Figure 2-3) for both 1998 and 2001. The difference between the "as flown" and great circle distances is referred to as "excess distance." Table 2-17 shows the excess distance flown in 1998 and 2001.

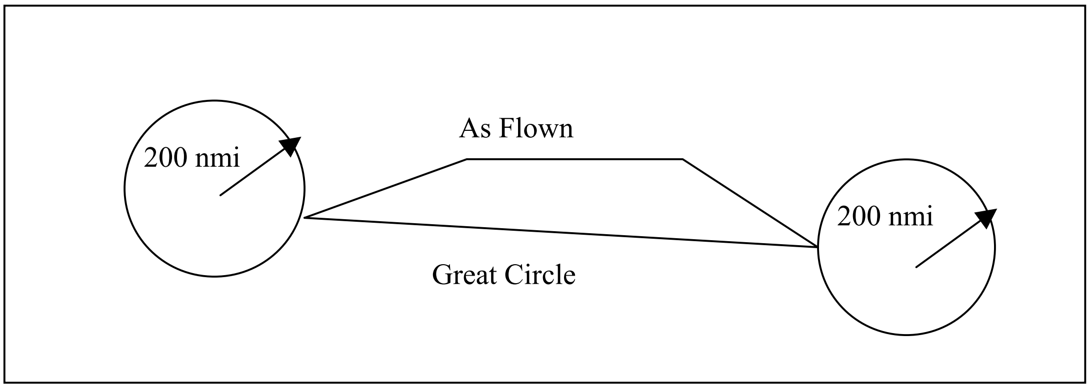

Figure 2-3: Excess Flight Distance Calculation Methodology

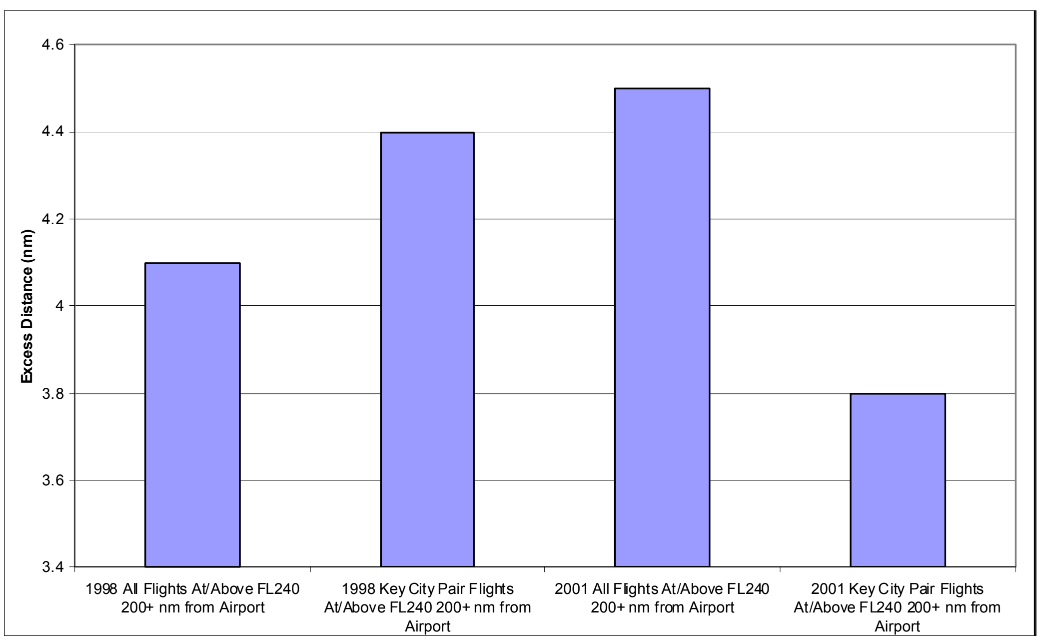

Figure 2-3: Excess Distance Flown (1998-2001)

Table 2-17: Excess Distance Flown (1998-2001)

Scope	Excess Distance Flown- 1998	Excess Distance Flown – 2001	Diff (nmi)
All Flights	4.1 nmi	4.5 nmi	+.4 nmi
Key 28 City Pairs	4.4 nmi	3.8 nmi	-.6 nmi

The difference in excess distance was then compared for the two years to estimate the distance potentially saved due to URET. This shows that flights between those city pairs, on average, saved .6 nmi once URET was used on a regular basis versus an increase of .4 nmi for all flights that exceeded FL240. Thus, an overall reduction in excess distance of 1 nmi. This is consistent with the findings reported by the URET benefits team.

2.3.3 Evaluation of 400 City Pairs

In this analysis, two ETMS days (one in 2001 and one in 1995) were used. All flights that crossed either ZME or ZID were extracted. These flights were then grouped by city pair and filtered for flights that were in the Centers at least 10 minutes. An additional filter was then applied such that every city pair had at least five flights crossing the region/day. It should be noted that this is based on only two days of data. The result of this analysis was a list of several hundred city pairs.

The next step was to extract the airborne time from the ASQP data across three years (1995, 1998, and 2000) for these selected city pairs. The results were filtered to include only the city pairs that had flights in all three years. This led to the final 400 city pairs.

The airborne time reported in the ASQP for the 400 city pairs was evaluated with the average and standard deviation being calculated. These values were then weighted by the number of flights occurring in the year of evaluation (2000) in order to provide a consistent and appropriately weighted airborne time. The results of this analysis are shown in Table 2-18.

Table 2-18: Impact of URET on Airborne Time (400 City Pairs)

	Airborne Time		
Years	Mean	Std Dev	ASQP Flights
2000	125.26	9.73	974,045
1998	124.68	9.65	913,069
1995	124.34	9.33	956,567

As the table shows the average flight time has increased by nearly 1 minute since 1995 with the larger portion occurring after 1998 (i.e., since URET IDU). In order to estimate competing impacts (e.g., increased demand) we then extracted airborne times for over 2,000 city pairs NAS-wide. Note: The average airborne time for the 2000+ city pairs is 20 minutes less than the 400 city pairs that generally have larger airports. These city pairs were based on the 100 busiest airports. All possible combinations (nearly 10,000) were selected and those that occurred in all three years were then evaluated. The results of this analysis are shown in Table 2-19.

Table 2-19: NAS Airborne Time (2,000+ City Pairs)

	Airborne Time		
	Mean	Std Dev	ASQP Flights
2000	104.89	8.21	4,790,352
1998	104.48	8.25	4,647,410
1995	103.98	7.88	4,535,066

The table shows a consistent increase in airborne time with a modest increase in the airborne standard deviation since 1995. There do not appear to be any competing effects that would explain the lack of URET impact on airborne time.

2.3.4 URET Summary Evaluation

The top-down approach showed that there is a sufficient pool of efficiency benefits to cover the claimed benefits in the IAR and Acquisition Program Baseline (APB). ASD-400 evaluated flight efficiency in the form of fuel usage, not distance saved that was applied by AOZ.

In the bottoms-up approach, we attempted to determine the impact of URET on flights through ZID and ZME since it was operational as a prototype. Two evaluations were performed: 1) a limited number of city pairs – intended to provide an upper bound on the benefits, and 2) a large set of city pairs to estimate lower bounds of benefits.

Evaluation 1 provided some indication of improvements in airborne time and the associated variability (standard deviation). These improvements were not compelling or conclusive. Evaluation 2 showed no improvement in airborne time or the variability when compared to changes in NAS-wide performance.

Additionally, we examined the impact on flight distance. In this analysis, we showed results consistent with the product team claims. The distance saved, however, does not appear to be directly convertible into time savings which are then monetized using Aircraft Direct Operating Cost (ADOC).

It is possible with the wider use of URET and the application of a NAS-wide approach the distance savings will continue to be realized. Also, it is recognized that URET is an enabling technology for other programs and procedural initiatives, as well as being supported by programs such as the Weather Radar Processor (WARP).

2.4 TMA Evaluation

Three methods were applied to evaluate TMA-SC. The first method, a data examination of widely reported and accepted data, evaluates the recent flight performance: 1) the pre-PCA and post-PCA performance based on the OPSNET data at MSP and MIA, and 2) the reported DOT on-time performance data at MSP.

The second method consists of a series of analyses. The primary analysis evaluates the airborne and filed flight plan performance of the *peak arrival times* at MSP for both pre-TMA and post-TMA. In addition, there are two separate complementary analyses (Sections 2.4.4 and 2.4.5) that evaluate TMA's performance based on its impact (pre- and post-implementation) on flight and airport performance (operations) at MSP. The first analysis provides an estimate of changing airport performance. The second analysis looks at flight performance (airborne time) for all flights arriving into MSP.

The third method uses two modeling approaches as forms of validation from the AOZ analysis driving the benefits streams in the IAR and APB. The first approach applies a discrete-event simulation model, NASPAC. It looks at the arrival delay mitigation impact, including the system impact, of a 1 and 3 percent reduction in inter-arrival separation at the four sites where TMA will be operable as a strategic tool in the TMU. The second approach applies a stochastic queuing model that examines decrementing current buffers to "optimal" buffers.

2.4.1 Data Examination Perspective

ASD-400 examined two primary data sources - the OPSNET and the DOT on-time performance reporting via the ASQP data. The next two sub-sections examine the pre- and post-performance at a couple of FFP1 sites.

2.4.1.1 OPSNET Data

OPSNET reported delays from January 2000 through August 2000, and January 2001 through August 2001 were evaluated. Order 7210.55B, Operational Data Reporting Requirements, dated June 11, 1999 prescribes guidance for delay reporting through OPSNET. The software, which was redesigned in 1999, has improved the quality of this system.

Tables 2-20 and 2-21 present the performance into MSP and MIA for both pre- and post-PCA. Note that the traffic levels through August of the respective year were virtually identical at MSP; and at MIA there was a very slight decrease. Keep in mind this is a very high-level view of the delays at these two sites that have been declared PCA for at least four months through September 2001. Per this data source, when the non-weather-related delays are examined as a group, it appears that TMA has not had any impact in mitigating long arrival and departure delays (15 minutes or more) at MSP and MIA.

Table 2-20: Performance at MSP

Timeframe	Average Daily Ops at MSP	Average Daily Ops through ZMP	Total Non-Weather-Related Delays	Arrival Delays (>15 minutes)	Dep Delays (> 15 minutes)	Delays (55 Airports)
1/00-8/00 (pre-PCA)	1,425	5,891	2,657	846	3,154	282,559
1/01-8/01 (post-PCA)	1,420	5,872	2,970	1,558	3,773	275,267
Difference (01 from 00) (pct)	-.35	-.32	+11.8	+84.1	+19.6	-2.6

Source: OPSNET (ATT-200)

Table 2-21: Performance at MIA

Timeframe	Average Daily Ops at MIA	Average Daily Ops through ZMA	Total Non-Weather-Related Delays	Arrival Delays (>15 minutes)	Dep Delays (> 15 minutes)	Delays (55 Airports)
1/00-8/00 (pre-PCA)	1,421	6,145	1,307	267	3,542	282,559
1/01-8/01 (post-PCA[4])	1,375	6,324	2,127	369	4,146	275,267
Difference (01 from 00) (pct)	-3.3	+2.8	+62.7	+38.2	+17.1	-2.6

Source: OPSNET (ATT-200)

[4] Miami Center went PCA in May 2001 – this implies approximately 50 percent (four out of eight months) of the time TMA was being utilized at full capability, the first four months it was in IDU status.

The definitions of a reportable and arrival delay per Order 7210.55B, *Operational Data Reporting Requirements*, are as follows:

Reportable delay - is delay to IFR traffic of 15 minutes or more, experienced by individual flights, which result from the ATC system detaining aircraft at the gate, short of the runway, on the runway, on a taxiway, and/or in a holding configuration anywhere en route should be reported.

Arrival delay - is when an aircraft is delayed 15 minutes or more in the adjacent tower en route or arrival Center's airspace due to a condition impacting the flow to the destination. It is categorized as a terminal delay and is charged to the arrival airport.

This results (based on the data) shows that there is no indication of an improvement in "bottom-line" flight performance that the FAA tracks since the implementation of TMA. While there are probably other reasons for the increased delays at MSP and MIA, further work needs to be done by AOZ to better understand the relationship between TMA's usage and the statistics reported through OPSNET. Clearly showing the tradeoffs and understanding the net effect of additional aircraft arrivals and departures during the peak arrival pushes relative to the changes in airborne and block times needs to be captured by AOZ as additional sites become operational. Table 2-22 shows the number of times that the number of arrivals exceeds 30 and number of operations exceeds 55 at MSP for April of 1998, 1999, 2000, and 2001.

Table 2-22: Number of Pushes Per Category at MSP

	4/1998	4/1999	4/2000	4/2001
Arrivals >30 per push*	40	26	80	71
Operations >55 per push*	42	67	146	87

* Local Peaks – May simply imply wider peaks rather than more large pushes

In both reporting periods, there was zero en route delays reported. En route delays occur when aircraft incur airborne delays of 15 minutes or more as a result of an initiative imposed by a facility to manage traffic. Typically, en route delays are rarely reported by the facility through OPSNET. From January to August 2001, only 48 of these en route delays at 10 airports were reported. Tracking these delays does not appear to have any value in any assessment.

A comparison of the performance of the close proximity airports that have TMA-SC in FFP1 are presented below in Table 2-23. This table illustrates the current number of reported delays. It should be noted, however, that the three Centers that have declared PCA in 2001 and were IDU in 2000 are showing increases in non-weather related delays.

With OPSNET published data there is no indication that the performance of TMA has improved operations at MSP and MIA regardless of how this data is interpreted. TMA-SC needs to be evaluated over the long term to measure the behavior and correlate it to the relevant OPSNET-reported delays. Perhaps evaluating the performance at the beginning of a key milestone like PCA is not a true measure of the expected added value of the tool, i.e., there is still a learning curve with the controllers and/or TMU specialists when metering traffic into the airports with this tool. Before taking this information, there needs to be a sense of how consistent the airport acceptance rates are increasing with TMA. If delays are being absorbed at higher altitudes (e.g., at the outer meter arc) than at lower altitudes, then it needs to be noted if the airlines are benefiting from reduced fuel costs, especially if the airborne times are not showing any signs of improving.

Table 2-23: OPSNET Delays at FFP1 Sites (January-August of 2000 and 2001)

Airport	# of 2000 Non-Weather Related Delays	# of 2001 Non-Weather Related Delays	Change (2000 from 2001) – Pct.	Status
LAX	1,413	2,310	+63.4	IDU 11/00
ATL	4,097	2,965	-27.6	IDU 2/01
MSP	2,657	2,970	+11.8	PCA 12/00
SFO	3,147	1,508	-52.1	IDU 8/01
MIA	1,307	2,127	+62.7	PCA 5/01
DEN	39	94	+241	PCA 3/01
NAS (60 Major Airports)	75,967	77,485	+2.0	

2.4.1.2 On-time Performance Data Examination Perspective

Examining DOT reported "on-time performance data" gives another perspective for measuring flight performance. In fulfilling DOT's data reporting requirements, the 10 to 12 reporting air carriers use automated and/or manual systems for collecting flight data. These flights have time stamps that are extremely accurate, i.e., wheels-off to wheels-on times and pushback from the gate to into the gate time. The carriers that use an automated system rely on the Aircraft Communication Addressing and Reporting System (ACARS). Northwest, the dominant carrier at MSP is one of the four carriers that use ACARS exclusively. The three others are American, United, and US Airways.

Table 2-24 shows the carrier reported 2000 and 2001 airborne times into MSP, 80 percent of the reported flights are NWA. Both the O-D pairs and demand into MSP have remained virtually identical during the two years. Despite the fact that TMA was not declared PCA until late-December 2000, the airborne times were about 1 percent less in 2000 when TMA was not declared PCA and had limited usage. The traffic demand was virtually identical. Assuming that the flight times to MSP's outer meter arc were about the same in both years, it is very difficult to isolate the performance from the outer arc on a flight-by-flight basis into the airport. The time from that portion of the flight needs to be collected and reported by AOZ when collecting airborne times at TMA sites. Again, similar to the OPSNET perspective presented in the preceding section, there are no indications through the on-time performance reporting that the airborne time is improving (or not getting worse) with TMA deployed.

Table 2-24: Airborne Time Comparisons at MSP (2000 and 2001)

All Flights						Late Flights		
Carriers	Total Reported Flts-2000	Total Reported Flts-2001	Avg. Airborne Time – 2000 (Min)	Avg. Airborne Time – 2001 (Min)	Diff % (2000 to 2001)	Avg. Airborne Time – 2000 (Min)	Avg. Airborne Time – 2001 (Min)	Diff % (2000 to 2001)
All Flights	99,312	99,424	113.8	115.2	+1.2	118.4	123.0	+3.9
NWA	80,492	80,245	116.5	118.6	+ 1.8	125.7	129.6	+3.1

Source: ASQP

In 2000, 66.7 percent of the flights flying to MSP adhered to their scheduled block times; in 2001, 66.1 percent of the flights adhered to their scheduled block times. This is virtually an identical result. Another perspective is to examine this data for the same period by looking at the behavior of the set of the block times that *do not adhere* to their block times. There were slight improvements in the number of minutes of delays, given that there is a delay in the first six months of the respective years. The time was reduced from 11.33 minutes to 11.14 minutes or a reduction of 1.7 percent. This is not a statistically significant result but it might be worth tracking. Regardless, it is critical that other airports are evaluated similarly by comparing identical city pairs during peak arrival pushes for the different evaluation periods.

2.4.2 Data Evaluation Perspective

ASD-400 performed this analysis in two ways: 1) a comprehensive analysis of 25 dominant departure cities with an emphasis on arrivals during the peak times, and 2) an examination of overall airborne time and airport performance at MSP both pre- and post-TMA implementation.

The detailed approach looks at the flight performance data and identifies the performance of operations primarily at a TMA site before and after the implementation. This effort involves establishing a pre-acquisition baseline for the FFP1 TMA-SC site and evaluates post-implementation performance at MSP. The overall approach examines airport performance as measured by post arrival and peak operations rates. Additionally, it evaluates airborne times for all arrivals into MSP.

2.4.2.1 Flight Performance Data

The ASD-400 assessment team extracted performance data from CODAS for 1999-2000 and ASPM for January - July 2001. These two data sources provide a breakdown of flight-by-flight performance metrics including departing/arrival airport, scheduled/actual arrival/departure times, airborne time, and filed-estimated time en route (ETE). The core metrics of our analysis are actual airborne time and filed-ETE.

To focus our analysis on consistent flight data, 25 airports having the majority of the flights into MSP in 1999 and 2000 were identified by average historical total monthly demand. The filter ensures that sporadic long haul or short-haul flights do not influence the data. In Table 2-25, these 25 airports departing to MSP are listed in order of average monthly demand down, i.e., ORD has the most departures into MSP and IAH has the fewest departures into MSP.

Table 2-25: Departure Airports into MSP

ORD	MDW	MEM	PHL	CLE
DTW	ATL	EWR	LAX	BOS
STL	CVG	SEA	SFO	DCA
DEN	MCI	MKE	OMA	LGA
DFW	PHX	LAS	IND	IAH

The analysis was narrowed to the peak arrival times when a metering tool such as TMA would have the greatest impact. The peak arrival periods were determined using the relative local maxima to retrieve the four highest periods, or "spikes," of the day. Extracting the peak arrival times required querying four days of ETMS arrival (AZ) tables to develop a moving 30-minute arrival count. ETMS was drilled down further to develop flight counts for each 10-minute bin based on the moving 30-minute arrival counts. The following peak arrival times were extended to total three 10-minute bins following the beginning of the peak time (1020, 1210, 1740, and 1930 local times), giving 30-minute peak times (see Figure 2-4). Also, the monthly arrival demands into MSP were extracted from OPSNET.

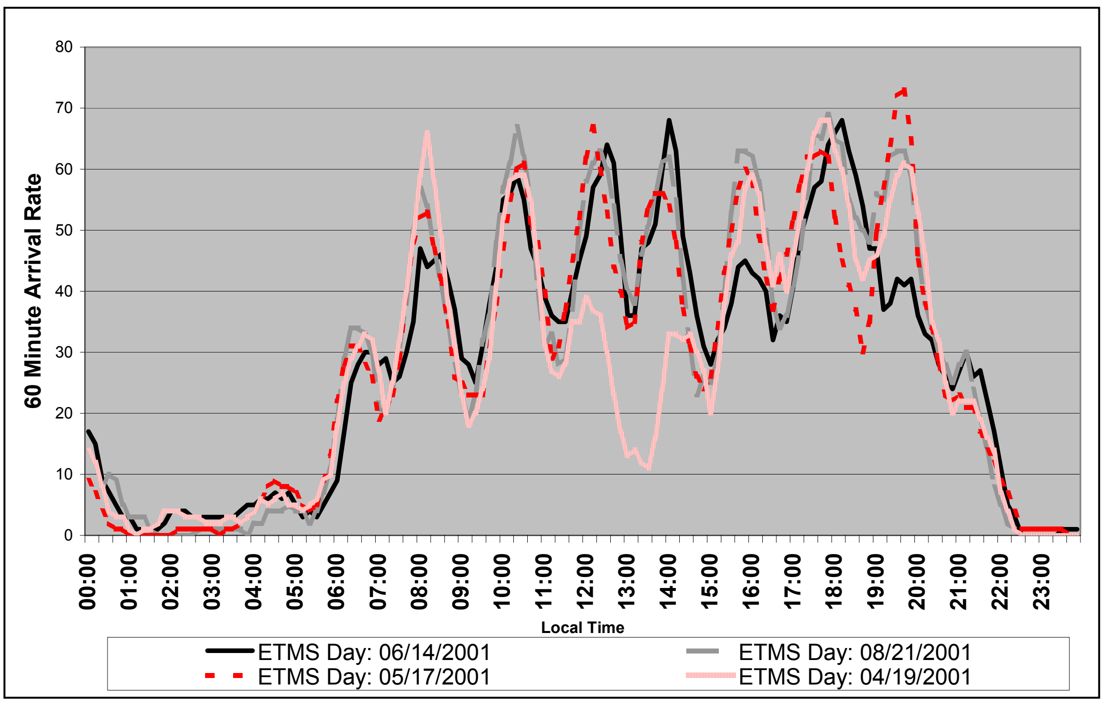

Figure 2-4: Hourly Flight Distribution at MSP

2.4.2.2 Weather Data

The FFP2 Benefits Assessment team used historical National Climatic Data Center (NCDC) surface hourly weather data to determine VFR and Non-VFR (MVFR and IFR) weather conditions at MSP. This data source provides hourly precipitation, ceiling, and visibility measurements. When weather conditions change, special observations within the hour are reported. The ceiling and visibility measurements provide the necessary metrics to determine whether VFR or Non-VFR conditions existed at the airport (see Table 2-26). The following guidelines were applied[5].

[5] Source: MSP tower input from ASD-400/ATP-100 - 2000 Airport Capacity Survey.

Table 2-26: Weather Criteria

Weather Condition	Minimums	Avg. Frequency
VFR	Ceiling >= 3500 feet AND Visibility >= 8 miles	68.5 %
Non-VFR	Ceiling < 3500 feet OR Visibility < 8 miles	31.5%

These criteria were assigned to each weather event. The weather events, with their respective assignments, were then mapped to those flights arriving during the weather period. Using this information, we can determine which flights arrive during VFR or Non-VFR periods.

2.4.2.3 Methodology

2.4.2.3.1 Pre- and Post-Implementation Periods

The pre- and post-implementation analysis involves identifying three stages of the product usage: pre-implementation, transition period, and post-implementation. For the purposes of this study, the pre-implementation period is the period of January 1999 to the TMA's Initial Daily Usage. The transition period, which is identified by the program office as six months at ZMP, is defined by the onset of IDU to the day of Planned Capability Achieved (PCA). PCA is defined by effective and fully qualified use of TMA. The post-implementation period is the period following the PCA date to July 2001. The FFP2 Benefits Assessment team identified the pre- and post-implementation dates for ZMP TMA as follows:

Pre-Implementation Period:	before 06/22/2000
Initial Daily Usage (IDU):	06/22/2000
Transition Period:	06/22/2000-12/20/2000
Planned Capability Achieved (PCA):	12/20/2000
Post-Implementation Period:	after 12/21/2000

2.4.2.3.2 Average Airborne and Filed-ETE Times

Using the January 1999 – July 2001 performance data we developed average airborne and filed-ETE times for each of the top 25 origin airports arriving at MSP for each month. The city pair averages were further averaged into monthly average airborne and filed-ETE times arriving into MSP. These monthly averages allow us to compare similar periods' historical performance and provide a basis to develop a forecast.

2.4.2.3.3 Forecasting with Exponential Smoothing

We used the SPSS Exponential Smoothing Model to project the pre-implementation period (January 1999 – June 2000) average monthly airborne times into the post-implementation months for each weather set, i.e., All, VFR, and Non-VFR. Filed-ETEs were evaluated in the all-weather set. The data within the transitional period was not analyzed within the pre-implementation data set to gain an accurate assessment of a pure system state without TMA implementation or TMA testing influencing the results. For each data set, the most appropriate model was a Damped curve model with a Least-Sum-of-Square-Error fit test.

2.4.2.4 Analysis

2.4.2.4.1 Demand

The historical arrival demand from OPSNET[6] was summarized within our definition of pre- and post-implementation for similar six-month periods. The six-month demand averages are grouped accordingly as shown in Table 2-27.

Table 2-27: Average Number of Daily Arrivals

Timeframe	Jan. 1999 – Jun. 1999	Jan. 2000 – Jun. 2000	Jan. 2001 – Jun. 2001
Number of Arrivals	685	708	708

2.4.2.4.2 Performance

The resulting data from the methodology provides performance figures for both Airborne and Filed-ETE times. Figures 2-5 and 2-6 illustrates separation by weather conditions and shows the following:

The System State of each graph includes:

- Pre-Implementation Period
- IDU and PCA dates
- Transitional Period
- Post-Implementation Period
- Forecasted Post-Implementation Period

Each graph also has Performance Metrics of:

- Average Daily Demand by Month
- Pre/Post-Implementation Actual/Forecast Airborne Times
- Pre/Post-Implementation Actual/Forecast-Filed-ETE Times (All Case)

Tables 2-28 and 2-29 (following each of the graphs) have additional metrics showing:

- Comparative six-month average airborne and filed-ETE times
- Post-implementation forecast based on all pre-implementation data

[6] The daily reporting is collected from FAA Forms 7230-1, Airport Traffic Record, 7230-12, Instrument Approaches Monthly Summary and 7230-26, Instrument Operations.

Figure 2-5 shows the Airborne and Filed-ETE performance for MSP aggregated for all surface weather conditions.

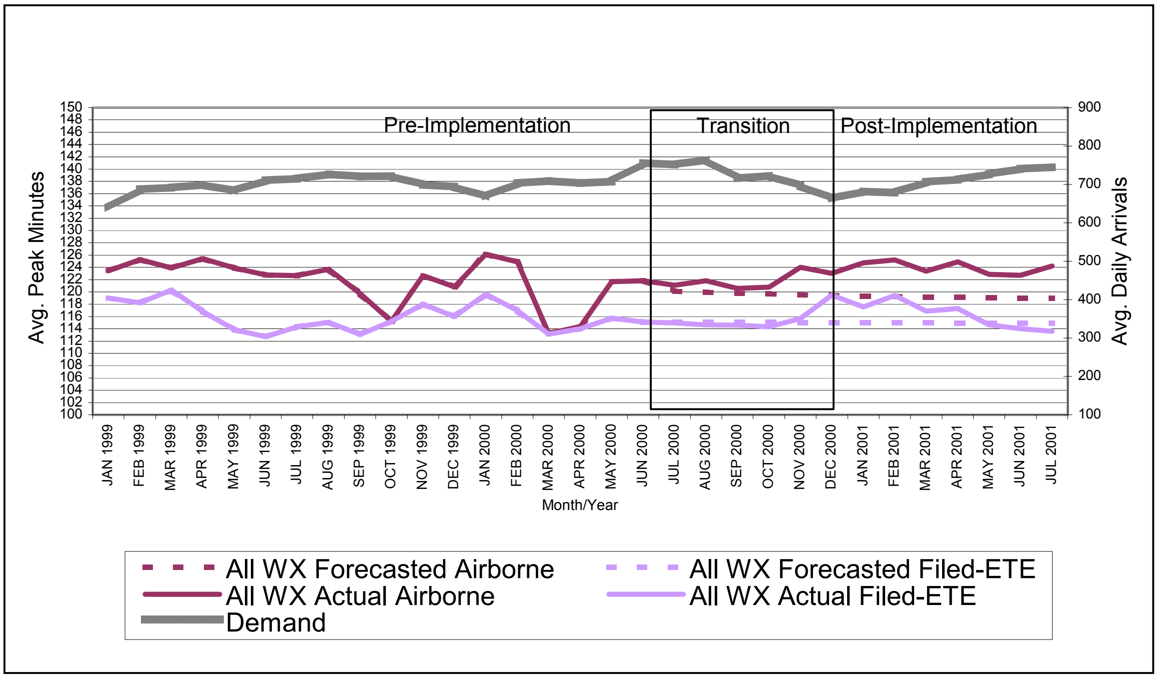

Figure 2-5: Pre/Post Implementation Results (All Weather)

Table 2-28: Summary of Flight Performance (in minutes) – All Weather Conditions

Timeframe	Jan. 1999 - Jun. 1999		Jan. 2000 - Jun. 2000		Jan. 2001 - Jun. 2001		Forecast	
	Airborne	Filed-ETE	Airborne	Filed-ETE	Airborne	Filed-ETE	Airborne	Filed-ETE
Time	124.1	116.8	120.4	115.8	124.0	116.6	119.2	114.9

The data in Table 2-28 above represents flight performance times during all weather conditions for similar six-month periods in each year. The resulting data shows a 3.7-minute decrease in average airborne time between the six-month periods in 1999 and 2000. However, the results show a 3.6-minute increase in the average airborne time between the six-month periods in 2000 and 2001. Also, from 1999 to 2001, the results show a .1-minute decrease.

The forecast produced a trend showing airborne times would decrease during the post-implementation period. This information suggests that the airborne times were decreasing over time during the pre-implementation period and were forecasted to continue decreasing. The actual post-implementation period, however, shows a marginal increase for all evaluated flights during all weather conditions.

The resulting data shows a 1.0-minute decrease in average filed-ETE times from the six-month period in 1999 to 2000. The filed-ETE times for the six-month period in 2001 show an increase of .8 minutes from the six-month period in 2000. The filed-ETE times for the six-month period in 2001 shows a marginal decrease of .2 minutes from the six-month period in 1999. The forecasted average filed-ETE times were predicted to continue decreasing through the post-implementation six-month period; however, the actual data show an increase. This data suggests the airlines were reducing their filed-ETE times through 2000, but increased them in 2001.

Figure 2-6 shows the airborne times during VFR weather conditions for MSP.

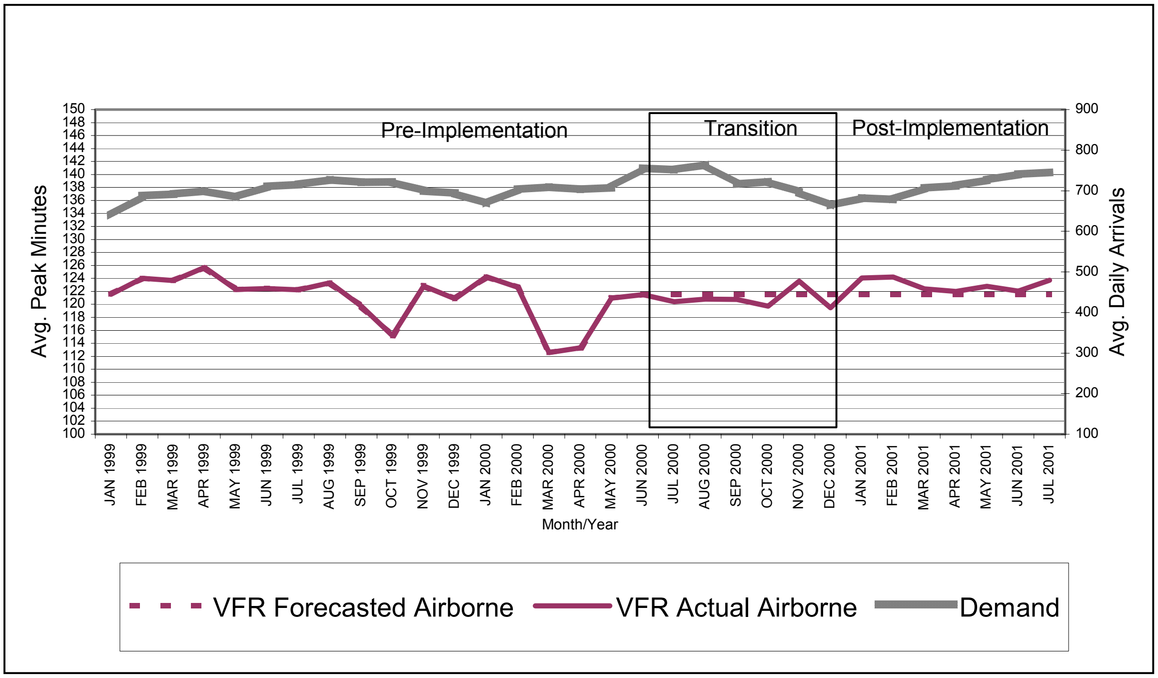

Figure 2-6: Pre/Post Implementation Results (VFR)

Table 2-29: Forecast Airborne Times (minutes) - VFR Conditions

Timeframe	Jan. 1999 - Jun. 1999	Jan. 2000 - Jun. 2000	Jan. 2001 - Jun. 2001	Forecast
	Airborne	Airborne	Airborne	Airborne
Time	123.3	119.2	122.9	121.5

The data in Table 2-29 above represents airborne times during VFR weather conditions for similar six-month periods in each year. The resulting data shows a 4.1-minute decrease in average airborne time in the six-month periods from 1999 to 2000. The results show a 3.7-minute increase, however, in the six-month periods from 2000 to 2001. Also, the results show a .4-minute decrease in the six-month periods from 1999 to 2001.

The forecast produced a trend showing airborne times would increase during the post-implementation period. This information suggests that the airborne times were decreasing, followed by an increase during the pre-implementation period and were forecasted to continue increasing. The actual post-implementation period shows a marginal decrease while the forecast times increase.

Figure 2-7 shows the performance of airborne times during Non-VFR weather for MSP.

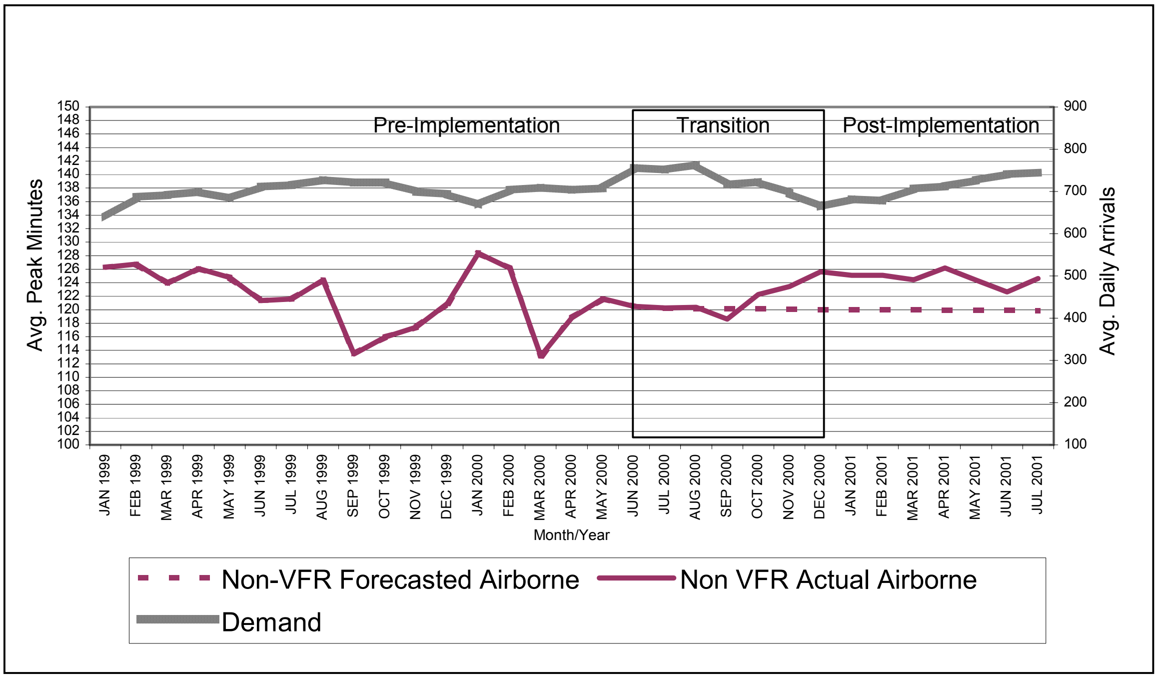

Figure 2-7: Pre/Post Implementation Results (Non-VFR)

Table 2-30: Forecast Airborne Times (minutes) - Non-VFR Conditions

Timeframe	Jan. 1999 - Jun. 1999	Jan. 2000 - Jun. 2000	Jan. 2001 - Jun. 2001	Forecast
	Airborne	Airborne	Airborne	Airborne
Time	124.9	121.4	124.6	120.0

The data in Table 2-30 above represents airborne times during Non-VFR weather conditions for similar six-month periods in each year. The resulting data shows a 3.5-minute decrease in average airborne time in the six-month period from 1999 to 2000. The results show a 3.2-minute increase, however, from the six-month period from 2000 to 2001. Also, the results show a .3-minute decrease from the six-month period of 1999 to 2001.

The forecast produced a trend showing airborne times would decrease during the post-implementation period. This information suggests that the airborne times were decreasing during the pre-implementation period and were forecasted to continue decreasing. The actual post-implementation period shows a marginal decrease smaller than the forecasted decrease.

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2.4.2.5 Conclusions

The analysis reveals that from the time TMA has been operational since PCA, the average airborne times from the 25 airports have increased during the six-month evaluation period by 3.6 minutes (3 percent) from the 2000-evaluation period (pre-IDU). With virtually identical demand, it is apparent that the implementation of TMA has not improved airborne flight times despite AOZ's observations that airport acceptance rates have been increasing during the peak arrival rates. Additionally, examination of post-TMA adherence of carrier filed-ETE time, an indicator of an airline's schedule predictability, reveals that airlines have not adjusted their scheduled filed-ETE times to be consistent with the distribution in airborne times that are occurring with time-based metering.

2.4.3 Flight Performance into MSP

In an examination of the overall airborne times, we extracted *all common city pairs* arriving into MSP during the first six months of 1999, 2000, and 2001. The results of this analysis are shown in Table 2-31. The airborne times are weighted by the number of flights for each city pair in 2001 to yield a consistent and comparable result. It can be seen that these results are based on different criteria from the results presented earlier. The earlier results are based on airborne times scheduled to arrive during the peak arrival pushes, whereas, these are overall airport results for all hours.

Table 2-31: MSP Arrivals Airborne Time

	1999	2000	2001
Flights	66,290	69,504	68,761
Average Weighted Airborne Time	115.27	115.24	115.33

Source: ASQP

As can be seen, there has been virtually no change in airborne time since 1999 and no conclusive impact of TMA on flight performance (i.e., reduced airborne time) since PCA.

2.4.3.1 MSP Airport Performance

In order to evaluate airport performance, the peak arrival pushes and the peak operations (arrival +departure) were examined. Since TMA went to IDU in June 2000 and PCA in December 2000, we examined April of 2000 and 2001 as the primary points of comparison (pre- and post-TMA). We also examined April of 1998 and 1999 for the sake of completeness.

We extracted all flights either arriving or departing from MSP during the month of April for 1998-2001 from CODAS and ASPM. The data was aggregated into moving 30-minute windows of operations (either arrivals only or all operations). During each 30-minute window, we determined if it was a local maxima (a push) and if that maxima exceeded 30 arrivals or 55 operations (equivalent to 60 arrivals/hour or 110 operations/hour). The inter-arrival and inter-operation times were extracted from each of the identified peak time periods. From this data the average and standard deviation were calculated and an overall average peak arrival/operations rate was determined. Tables 2-32 and 2-33 display the results of this analysis.

Table 2-32: TMA Impacts on MSP Arrivals

	April - MSP Arrivals			
	1998	1999	2000	2001**
Inter-arr Time at peaks (min)	0.979	1.011	0.973	0.967
Std Dev at peaks	0.737	0.721	0.846	0.870
Flights	16,523	17,297	18,100	18,724
Num Peaks>30*	40	26	80	71
Peak Arr Rate/Hr	**61.28**	**59.33**	**61.69**	**62.03**

Source: CODAS and ASPM

Table 2-33: TMA Impacts on MSP Operations

	April - MSP Operations (Departures and Arrivals)			
	1998	**1999**	**2000**	**2001**
Inter-Operation Time at peaks (min)	0.539	0.538	0.519	0.518
Std Dev at peaks	0.541	0.511	0.528	0.572
Flights	33,067	34,592	36,203	37,390
Num Peaks>55*	42	67	146	87
Peak Ops Rate/Hr	**111.29**	**111.49**	**115.54**	**115.90**

Source: CODAS and ASPM
** Local Peak - More may mean simply wider peak*

Based on these results, there seems to be a significant change in peak operations between 1999 and 2000; however, this is prior to TMA IDU and PCA status. Arrivals show a similar trend with only a small increase between 2000 and 2001. The number of arriving flights and departing flights has increased by over 3 percent. The variability of the inter-arrival times at the peaks also has trended upward over the last year.

While this data does not show an increase in the peak inter-arrival rate, it should be noted that the product team used the Automated Radar Terminal System (ARTS) data, which has a much higher fidelity in producing the "true" arrival rates. The CODAS/ASPM data is coarser and in many cases used an estimated arrival time from ETMS, which is known to have significant accuracy problems. Thus, although we could not confirm the product team claims of increased peak arrival rates, a key driver for the benefits estimation, this easily could be the result of the data source.

2.4.4 Modeling Future Impacts of TMA-SC

ASD-400 performed two quick modeling exercises. The goal of these exercises was to conduct sanity checks of TMA's potential contribution, while comparing the results to the AOZ results that are being presented in the IAR and APB. While it is very time consuming to make an apples-to-apples comparison between each model, the two modeling efforts applied several of the same or similar attributes. Table 2-34 highlights key attributes for each model.

Table 2-34: Key Attributes Between Modeling Approaches

Attribute	NASPAC	AOZ Deterministic Queuing Model	ASD-400 Stochastic Model
Airport Capacity	2000 Capacity Survey and FAA Capacity Benchmark Study	FAA Capacity Benchmark Study	2000 Capacity Survey
AT Actions	Dynamically puts miles-in-trail (MIT) on flights when sector demand exceeds capacity threshold	None	Average wait time savings in queues cannot exceed 5 minutes
Capital Improvements	Planned runways	Planned runways + ADS-B, LAAS, RNAV/FMS	Planned runways + ITWS, PRM, WAAS/LAAS
Current Demand	Scheduled flights in OAG + IFR flight plans from ETMS. Adjusted to comply with official air traffic counts.	IFR flight plans from ETMS	Scheduled flights from OAG + adj. non-scheduled flights (three consecutive peak hours of five weekdays)
Delay Computation	Simulation - operational (arrival and departure delay) based on difference in reference case and AAR increases of 1% and 3%	Simulation- operational arrival and departure delay difference in reference case and most likely AAR increase	Analytical - savings difference from average historical ASQP delay
Fleet Mix	All aircraft	All aircraft	All aircraft (ARTS data used to calculate buffers)
Future Demand	Frataring algorithm[7], which spreads demand during day. Growth rate consistent with 12/01 TAF demand two days (scaled back two years).	Spread proportionally by hour consistent with airport growth rate per new TAF	Spread proportionally by hour consistent with airport growth rate per 12/01 TAF
Number of Days Modeled	One good day, One bad day – 24 hour days	One representative week – 24 hour days	N/A – analytical (based on averages) – contiguous three-hour peak arrival time
Number of Servers	Two per active airport (departure and arrival servers) for most used VMC and IMC configuration	One per active runway based on combination of active configurations	One per active airport
Phase In of Capability	At IDU. adjustments to interarrival separations	Yes, learning curve between IDU and PCA. Increased arrival rate of 2.4 percent in 1st deployment phase; 3.0 percent for arrivals and departures during the 2nd phase which reflects transition to time-based metering	At PCA – adjustments to interarrival buffers
System Impact	Yes, evaluates subsequent legs from flight itineraries--minor impact	No	No
Type of Model	Discrete-event simulation (network of servers)	Deterministic – 2 servers	G/G/1 – analytical approximation
Weather	Representative IMC and VMC day	Average week, not sure of frequency of IFR runway configurations	Per capacity model and IMC, VMC per climatological weather data

2.4.4.1 Discrete-Event Simulation Perspective

This approach applied a discrete-event simulation model, NASPAC. ACB-330 supported ASD-400 with a very quick turnaround NASPAC simulation by adjusting inter-arrival separations at the four airports where the TMA will meter flights during peak arrival times.

[7] The Frataring algorithm is a trip distribution technique that applies an iterative process to scale up the current origin/destination matrix consistent with the forecasted yearly growth factor in the TAF. The future flights are strung together into aircraft itineraries and are spread out during the day, while dynamically balancing the airport traffic and preserving the airport's bank operations.

The analysis evaluated future operations at CVG, IAH, MEM, and STL based on the airport's projected demand growth from 2001 baseline year. Airport capacities used in the analysis reflect all runway improvements expected to be completed per the 2001 Airport Capacity Enhancement (ACE) Plan and the OEP within the modeled time frames. Table 2-35 illustrates the capacities, both VMC and IMC configurations, that were applied through 2015. Table 2-36 shows the reported arrival demand for the baseline year 2001 with the forecast for the future years. The counts are from the OPSNET reporting system (FAA's official mechanism for capturing traffic counts).

Table 2-35: Maximum Arrival Capacities at Four Airports – Reference Case

Airport/ Center	Max Hourly Arrival VMC Capacity			Max Hourly Arrival IMC Capacity			Percent IMC	New Runways, Procedures
	2005	2010	2015	2005	2010	2015		
CVG (ZID)	105	105	105	61	61	61	15.3	X – 2005
IAH (ZHU)	110	110	110	88	88	88	12	X – 2005
MEM (ZME)	88	88	88	60	60	60	22.9	None
STL (ZTL)	66	66	100	45	54	54	17.0	X – 2007

Table 2-36: Actual and Projected Arrivals Simulated in Model

Airport	Projected 2005 Daily Arrivals in Model[8]	OPSNET Reported Average Daily Arrivals (April 2001)	Difference Pct. (2001 to 2005)	Annual Pct. Increase (2001-2015)
MEM	553	540	2	2.6
STL	716	679	5	3.8
CVG	682	650	5	2.7
IAH	747	680	10	2.6

In AOZ's deterministic queuing application, each of the airport acceptance rates were initially increased by 2.4 percent based on experience at ZLA/LAX during peak arrival periods. In subsequent years with the assumption of time-based metering giving slightly more capability, the rates were scaled up linearly to 3.0 percent through the end of the life cycle. In contrast, ACB-330 applied changes in the arrival capacity by reducing inter-arrival times by either 1 or 3 percent between successive flights at each of the four airports. The other NAS airports did not change from their base case future capacities except allowances for new runways.

NASPAC simulations were conducted to assess the mitigation of arrival and departure delay at the four airports as well as system impacts through the NAS. System impacts are important because frequently a very late arrival to one airport will cause some of the passengers to miss their subsequent flight or that late arriving flight leaves the gate for its next flight behind its scheduled time. System delay reduction, which reflects the propagation of delay through the subsequent flight legs with the same aircraft, had a relatively small impact at the other airports from the reduction in inter-arrival time at the four evaluated airports.

Two weekdays were modeled: 1) a good weather day in which 95 percent of the time the major NAS airports were using visual approaches, and 2) a poor weather day in which approximately 65-70 percent of the time the airports were using visual approaches. Weekend demand was not considered since it is approximately 85 percent of the weekday demand and typically has much

[8] Demand scaled back by two years from December 2001 TAF, which did not account for impact from September 11, 2001.

less overall impact than a busier weekday. Next, the results were generated from the simulation for the two days and the future demands were applied using the FDG for years 2005, 2010, and 2015 scenarios. Then, a very crude extrapolation based on 240 VFR days and 20 IFR days and 220 VFR days and 40 IFR days (260 days reflect only weekdays) was assumed for giving what should be considered a rough-order-of-magnitude (ROM) estimate of annualized numbers. In addition, the TAF was scaled back two years to account for the drop in traffic levels following September 11, 2001, e.g., the 2005 demand was made consistent with the previous 2003 demand per the December 2001 TAF.

The NASPAC model reports operational delay, which includes the amount of time flights are prohibited from landing because the runway is in use or airborne holds in the terminal area occurred and the time held on the ground (both at the gate and in the taxi queue) because an arrival had to land. NASPAC also reports passenger delay, which measures the difference between the simulated and scheduled arrival times. This analysis does not consider passenger delay since we feel it is of small consequence (regardless of what the official APO guidance stipulates) when measuring the operational impact of a metering tool such as TMA. Baseline scenarios for each modeled year were developed so that comparisons could be made between each of the scenarios that reflect arrival capacity changes, e.g., if there are 60 arrivals per hour this translates to about two additional arrivals per hour in the 3-percent reduction case. In this way, we were able to estimate the operational impacts from the capacity changes that these four airports have on the NAS.

Results were derived for both good and bad days and annualized as noted above. Tables 2-37 and 2-38 show the delays, which are primarily airborne delays, for both the 1 and 3-percent reductions in inter-arrival separations relative to the baseline. For simplicity sake, three scenario years: 2005, 2010, and 2015 were run. Also, due to very limited time to complete the analysis, these separations were adjusted for all airports beginning in 2005, i.e., we did not get down to the level of granularity that AOZ applied with the IDU, PCA, and the time-based-metering phasing in. This explains why the benefits are coming in 2005 faster than the AOZ estimate.

Table 2-37: Annual Delay Savings by Weather Type From Baseline (1 and 3 Percent Inter-arrival Separation Reduction) - hours

Case	2005			2010			2015		
	VFR Days	IFR Days	Total	VFR Days	IFR Days	Total	VFR Days	IFR Days	Total
1 pct decrease	3083	419	3502	2370	345	2715	2761	488	2273
3 pct decrease	4349	631	4980	5008	667	5675	8787	946	9733

Table 2-38: Annual Delay Differences by Weather Type From Baseline (1 and 3 Percent Inter-arrival Separation Reduction) - $M then-year dollars

Case	2005			2010			2015		
	VFR Days	IFR Days	Total	VFR Days	IFR Days	Total	VFR Days	IFR Days	Total
1 pct decrease	5.9	.80	6.7	4.99	.73	4.9	5.3	1.2	6.5
3 pct decrease	8.3	1.2	9.5	10.5	1.4	11.9	20.4	1.7	22.6

The results show that in the 3-percent case, the per day delay savings of operations during IMC is slightly higher than on a VMC day. By 2015, the average flight delay savings from the baseline case of all the flights (the denominator is **all the operations** for the respective airport) that arrive at the four airports is about a .20-.25-minute savings per flight.

Based on this quick validation, it appears that the AOZ methodology is credible; however, the -AOZ results appear overstated, primarily because of the delays showing in MEM, which are two-four times higher than the other airports, i.e., approximately 1.50 minutes per flight, with the majority of the hours saved (by a 2:1 ratio) from departure delays. Only a *portion of the daily flights will actually interact with TMA* since there are only a limited number of arrival pushes on a typical day. The ASD-400 upper-bound results using a 3-percent inter-arrival reduction factor projects to about one-half of AOZs claimed savings by 2010 and one-third the claimed savings by 2015; the 1-percent case is significantly lower.

In summary, this exercise points out that the projected timesavings from metering with TMA-SC is estimated to be substantially less than what is being presented in the APB and IAR. Comparisons were not made to the inputs and logic of the simulations. There are a variety of reasons for differences in results whenever simulations with different models using different data, different algorithms with different analysts are conducted. There are differences in the logic: one significant difference could be the way NASPAC spreads the future traffic as it approaches the capacity through a FDG, whereas, the AOZ method grows demand irrespective of the airport capacity. Another difference may be how the NASPAC model is dynamically adjusting the flows via increased MIT when the sector demand exceeds the MAP threshold; the AOZ approach does not cap the duration of any airborne holds. Additional excursions need to be done on both models in the model formulation, verification, and validation phases to clearly understand when and how the delays are accumulating.

2.4.5 ASD-400 TMA Assessment – Stochastic Queuing Modeling

This approach applied a stochastic queuing model. We assumed that the primary goal of TMA is to increase the precision and consistency of the inter-arrival spacing of aircraft on both visual and instrument approaches. Our goal is not to define the optimum spacing, nor to explore the boundaries of minimum spacing. Rather, our objective is simply to exploit the potential of TMA to allow the controller to manage more precisely the sequencing of arriving aircraft into an airport.

Managing the spacing between successive aircraft on arrival paths in the terminal area can be challenging for both pilots and controllers, and the consequences for operating on either side of the "optimum" spacing are significant. If an aircraft is too close to a preceding aircraft, a go-around may be necessary. On the other hand, runway capacity is wasted when the gap between successive aircraft is excessively large. Consistently achieving inter-arrival spacing closer to the optimum is an important step in reducing terminal area congestion.

The reduction in arrival delay benefits were estimated based on expected airport capacity improvements due to more consistently achieving closer to optimal aircraft spacing. Due to the existing challenges of managing aircraft spacing, pilots, and controllers often add a buffer over and above the prescribed separation standards. With the capabilities provided by TMA, it was estimated that this additional separation buffer could be reduced and that airports would operate closer to the optimal spacing and, therefore, achieve efficiency gains.

Estimates were developed separately for CVG, IAH, STL, and MEM, all of which are scheduled to receive TMA in Phase 2. The benefits were estimated for a consecutive three-hour peak period at each airport for weekdays only. TMA functionality was assumed to begin in 2005 at IAH and STL and 2006 for CVG and MEM.

Airport capacity was estimated for the baseline scenario as well as for the improvements associated with TMA. The baseline airport capacities were provided from the 2000 Airport Capacity Survey that was done by ASD-400 and ATP-100. The FAA study includes estimates for the capacities projected capacity levels in 2005, 2010, and 2015. The future baseline capacities include improvements anticipated due to other programs such as ITWS, PRM, and WAAS/LAAS. Any additional improvement attributable to TMA was incrementally measured to the capacity levels based on these other programs.

The baseline capacities provided by the FAA study were modified to capture hourly fluctuations based on the traffic mix over the three-hour peak period, as well as the separation standards and additional spacing buffers. Peak period traffic mix was measured using ETMS data to determine the percentage of operations by aircraft type and the percentage of arrivals versus departures. Separation standards incorporate the impact of wake turbulence separations and were estimated in seconds based on inputs from air traffic representatives and commercial operators as to the prescribed distances and typical approach speeds. Table 2-39 summarizes the estimated separation standards for all combinations of aircraft types for both arrival and departure operations.

Table 2-39: Separation Minimums (Seconds)

Arrival Following Arrival

	Preceding Aircraft			
Following Aircraft	Heavy	B-757	Large	Small
Heavy	108	108	81	81
B-757	107	107	80	80
Large	137	110	82	82
Small	214	178	143	107

Arrival Following Departure

	Preceding Aircraft			
Following Aircraft	Heavy	B-757	Large	Small
Heavy	51	48	47	43
B-757	51	48	47	43
Large	51	48	47	43
Small	51	48	47	43

Departure Following Departure

	Preceding Aircraft			
Following Aircraft	Heavy	B-757	Large	Small
Heavy	89	89	80	65
B-757	120	72	80	50
Large	120	80	80	50
Small	120	120	100	65

Departure Following Arrival

	Preceding Aircraft			
Following Aircraft	Heavy	B-757	Large	Small
Heavy	72	65	62	80
B-757	72	65	62	80
Large	72	65	62	80
Small	72	65	62	80

Capacity improvements were estimated using an assumed reduction in the excess spacing buffers. The buffer associated with an arrival following another arrival were estimated using an analysis of radar data from MEM. Additionally, due to the capacity constraints at high traffic density airports with Level 5 towers, i.e., CVG and STL, the excess spacing buffers at these locations were assumed to be only 15 percent of the initial values estimated. Table 2-40 lists the separation buffers for airports with Level 4 towers, i.e., MEM and IAH, and includes a footnote regarding the reduced magnitude of these buffers at airports with Level 5 towers.

Table 2-40: Additional Separation Buffers (Seconds)

Arrival Following Arrival

Following	Preceding Heavy	B-757	Large	Small
Heavy	33	56	79	60
B-757	33	56	79	60
Large	13	35	56	48
Small	60	40	20	103

Arrival Following Departure

Following	Preceding Heavy	B-757	Large	Small
Heavy	26	26	26	26
B-757	26	26	26	26
Large	26	26	26	26
Small	26	26	26	26

Departure Following Departure

Following	Preceding Heavy	B-757	Large	Small
Heavy	25	25	25	25
B-757	25	25	25	25
Large	26	26	25	25
Small	27	27	26	25

Departure Following Arrival

Following	Preceding Heavy	B-757	Large	Small
Heavy	26	26	26	26
B-757	26	26	26	26
Large	26	26	26	26
Small	26	26	26	26

Note: Separation buffers applied to airports with Level 4 towers and below. Separation buffers reduced to 15% for airports with Level 5 towers.

Based on the capabilities provided by *TMA*, it was assumed that the spacing buffers cited in Table 2-41 could be reduced by 18 percent for the instances when an arrival follows another arrival, e.g., a large aircraft behind another large aircraft would be 35 seconds times .18 or about a 6-7 second buffer. Table 2-41 summarizes the resulting airport capacity increases by year.

Table 2-41: Capacity Increase Per Year (Number of Arrivals)

Airport	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
CVG	0	0	0	0	1	1	1	1	1	1	1	1	1	1
IAH	0	0	0	3	3	3	3	3	3	3	3	3	3	3
STL	0	0	0	1	1	1	1	1	1	1	1	1	1	1
MEM	0	0	0	0	3	3	3	3	3	3	3	3	3	3

Baseline and improved airport capacities in both VMC and IMC were compared with projected traffic demand to determine the percentage delay reduction that results from reductions in spacing buffers. Future peak period demand was estimated by inflating the existing level by the overall growth in traffic documented for each airport in the 2000 TAF. For delay reduction purposes, the hourly demand rate was constrained by the hourly airport capacities.

Using equilibrium queuing theory, an upper bound on the average delay was calculated for both the baseline and improved capacity cases. Assuming both demand and capacity can be represented by general distributions, the upper bound on the average wait in the queue for any *G*/*G*/1 queue is:

$$W_q \leq \frac{\lambda\left(\sigma_A^2 + \sigma_B^2\right)}{2\left(1 - \lambda/\mu\right)} \qquad (1)$$

where:
W_q is the average wait time (i.e., delay),
σ^2_A is the variance of the demand rate (i.e., time between operations entering the queue),
σ^2_B is the variance of capacity rate (i.e., time between operations exiting the queue),
μ is the average capacity rate, and
λ is the demand rate.

In heavy traffic, the average delay approaches its upper bound. In other words, the inequality becomes an equality.

Based on data analysis at MSP, we further assumed that variances would remain unchanged between the improved capacity and baseline capacity scenarios. The ratio between the upper bound for the average wait in queue associated with the improved capacity to the comparable value for the baseline capacity was used to determine the percentage reduction in delays. The existing baseline level of delay over the three-hour peak period for each airport was estimated based on data from the CODAS. The baseline levels of delays were projected to increase based on the percentage increase in the upper bound for the average wait in queue when computed using the existing baseline for capacity and demand as compared to when computed using the projected future baselines for capacity and demand. The percentage delay reductions were then multiplied by the baseline delays to determine the delay savings per arrival and departure. The average delay savings were constrained to be no more than 5 minutes per operation to limit the impact of queuing on escalating delays. The total annual delay savings for both VMC and IMC are tabulated in Tables 2-42 and 2-43.

Table 2-42: Annual Delay Savings (hours) VMC

Airport	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
CVG	0	0	0	0	39	47	56	68	82	100	115	142	177	207
IAH	0	0	0	459	475	487	502	518	534	549	565	577	593	608
STL	0	0	0	30	34	42	49	57	66	84	100	119	142	190
MEM	0	0	0	0	28	30	38	46	58	72	91	115	148	193
Totals	0	0	0	489	576	606	645	689	740	805	871	953	1060	1198

Table 2-43: Delay Savings (hours) IMC

Airport	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
CVG	0	0	0	0	54	69	90	120	162	228	292	443	483	489
IAH	0.	0	0	168	174	178	184	190	195	201	207	211	217	223
STL	0	0	0	15	15	16	16	16	17	17	17	17	18	18
MEM	0	0	0	0	16	18	23	28	36	45	58	75	99	133
Totals	0	0	0.	183	259	281	313	354	410	491	574	746	817	863

As an illustration, the results indicate that in 2010 a total of 1,150 hours of arrival delay can be saved with the more efficient metering tool such as TMA. It is felt that there are limited ground delay savings. This estimate is significantly below the AOZ estimate of 22,000 hours of annual delay savings in 2010 and 30,000 hours of annual delay savings.

2.4.6 Review of AOZ's TMA Analysis

ASD-400 reviewed the approach AOZ took to measure the impact of the FFP2 TMA sites. AOZ applied a deterministic queuing model that projected delay savings from the assumption of increased airport acceptance rates during the peak arrival times. Over 22,000 hours of delay savings were projected at the four airports in 2010; over 30,000 hours of delay savings were projected in 2015. Approximately 67 percent of these delay savings were projected to be on the ground (reduction in taxi-out times). ASD-400 observations and comments are described in Section 3.0 of this assessment.

2.4.7 TMA Summary Evaluation

ASD-400 applied three methods (data examination, data evaluation, and modeling) to measure the present and expected future performance of TMA. At this time, based on the analyses, there is minimal evidence that the flight-time performance at MSP has improved from the PCA date[9]. Despite the fact that peak hourly arrival rates have been shown by AOZ to increase by one arrival per hour and peak departure rates increase by 4-5 departures per hour, the bottom-line of overall improvements in flight time performance is not occurring. Airborne times and delays increased from pre-TMA deployment to post-TMA deployment regardless of what data source, i.e., OPSNET, ASQP, CODAS, and ASPM, is used as demand at the airport has remained unchanged. Moreover, it is difficult to support the projected delay savings from additional departures when time-based metering since average taxi-out times in 2000 and 2001 at MSP (a site with time-based metering) have increased by an average of .30 minutes per peak arrival push. Taxi-in times during these pushes have increased slightly as well. These findings contradict AOZ's modeling results that are showing significant departure delay savings when time-based metering begins at all FFP2 sites.

Predicting results with a deterministic queuing model when actual data at a deployed site(s) has not shown added value of the tool is a high-risk approach. Future tracking and benefits estimation need to *collectively evaluate the wide range of metrics* that were identified for specific outcomes in the FFP2 Integrated Program Management Plan, dated June 12, 2002, not a supporting metric such as peak arrival rate change. As the TMA program moves forward, the additional metrics (i.e., mean flight time, mean and variability of fuel usage, and mean arrival delays) supporting the increased throughput claim need to be baselined at each site to establish reasonable before and after flight performance levels. Many of these additional metrics will be tracked as the OEP Metrics Plan is being executed.

2.5 CRCT Evaluation

CRCT is a program that was developed by Center for Advanced Aviation System Development (CAASD) to aid traffic managers in analyzing traffic demand to determine congested airspace, in determining alternate routes that can be used to avoid congestion or inclement weather cells, in evaluating proposed routes, and in sharing data with other facilities. CRCT was initially developed as a standalone tool. CRCT prototypes are installed at ATCSCC, Kansas City ARTCC (ZKC) and ZID (Indianapolis ARTCC). CRCT functionality will be incrementally incorporated into ETMS. According to MITRE/CAASD representatives, the following is an incremental schedule of the installation of CRCT functionality into ETMS: June 2001, basic flow constrained areas (FCA) functionality was introduced in ETMS 7.2.6; October 2001, CRCT reroute functionality was installed; November 2001, enhanced FCA functionality incorporated into ETMS 7.3; *National Playbook Reroutes scheduled to be incorporated into ETMS 7.4; all remaining re-routing functionality is scheduled to be installed in ETMS 7.5*. CRCT information (such as FCAs) is displayed on the Traffic System Display (TSD) at ARTCCs and on the Common Constrained Situation Display (CCSD) at Airline Operations Centers (AOCs).

[9] In the BOE section of the IAR, AOZ stated that the full potential of the delay savings accrue at the beginning of PCA. Time-based metering is assumed to enhance the capability about 6-to-14 months after PCA at each site.

2.5.1 CRCT Users' Opinions/Anecdotal Information

CRCT functionality has the potential to be one of the most powerful en route collaborative traffic flow management tools. The most important feature of CRCT functionality is the ability to manually create/draw a FCA around bad weather cells or congested airspace due to volume. Not only can an FCA be drawn, it can be adjusted according to (weather) forecasts. There also is the option of setting starting and end times and designating a floor and ceiling for the FCAs. TMUs at ARTCCs can create FCAs/FEAs, after a Strategic Planning Team (SPT) telecon. The TMUs can then determine a set of reroutes, which could be flown in lieu of planned routes that were scheduled to fly through the FCA. It should be noted that the reroutes may be National Playbook routes or Coded Departure Routes, which are not in ETMS currently, but can be obtained from the Route Management Tool (RMT) or another display unit or decision-support tool. Re-routing information could be shared with other TMUs through the TSD and delivered to AOCs through the CCSD. If the ARTCC chooses to share the information with the ATCSCC, the ATCSCC would evaluate the FCA and may determine that it needs to be disseminated nationwide.

Many users have extolled the capability and flexibility of designing FCAs. No such capability was available previously, thus, re-routing around congested airspace was done in an ad hoc manner and based on conjectures about the fixes that were impacted. Another positive aspect of CRCT functionality is the ability to gauge the impact of proposed reroutes on sector loadings. This type of information is displayed in the NAS monitor. TMU, in any given ARTCC, has the option of looking at its Center's airspace and the individual sectors in the Center. This particular feature has been the most widely used feature especially at AOCs.

There is some concern that the development of the tool was not done collaboratively with the airlines, though it is meant to be a collaborative tool. According to a Northwest Airlines (NWA) chief dispatcher, the re-routing tool should be "AOC-driven and not TMU-driven." The AOCs would like the flexibility to determine their own reroutes around congested airspace. In the dispatcher's opinion, (due to an airline's economic objectives) AOCs would be most comfortable if TMUs used the re-routing functionality to determine the most effective reroutes and then give the AOCs a set of reroutes from which to choose. NWA believes that the maturation of the CRCT tool and procedures will develop after extensive Human-in-the-Loop (HITL) testing, which should include airline participation. AOCs will most likely use the tool consistently after the HITL testing has been done and after the maturation of the procedures.

CRCT re-routing functionality assists in analyzing what-if scenarios and the impact of proposed reroutes, but not the impact of the execution of proposed reroutes. The difficulty comes in executing reroutes in the form of resource allocation, not in proposing reroutes. According to the CDM program manager, compliance to plans is of premier importance. CRCT functionality aids in effective en route planning. If this planning could help in increasing compliance to plans, then this would be a tremendous benefit that could be attributed to CRCT.

2.5.2 Overview of CRCT Benefits in the IAR

Currently, reports have been written on expected operational impacts and benefits due to CRCT. Based on an analysis of pre-CRCT versus post-CRCT scenarios, CAASD analysts have concluded that some of the benefits, due to CRCT functionality, are decreased flight times and distances, decreased departure delays, and reduced flight cancellations and diversions. These benefits were estimated due to lack of operational data at the time the analysis was being done.

The analysis was broken into two categories: good weather and severe weather. Regression analysis was used to estimate the total amount of "excess time required to traverse terminal and en route airspace" (referred to as flight impedance) during good weather. A more detailed explanation of the determination of flight impedance is needed. An average impedance time was calculated for a small number of airports, then generalized to the top 31 airports, annualized for the number of good weather days, multiplied accordingly for traffic growth, converted to dollar numbers using ADOC and PVT values, ramped-in to include all CRCT functions, and then extrapolated for future years. During severe weather, the re-routings, cancellations, diversions, and ground delays were considered. Benefits in these areas are in the form of more efficient re-routings (miles saved per flight) and a reduction in the number of diversions, the number of cancellations, and the amount of ground delays (minutes saved per flight). The savings determined in these categories were annualized for the number of severe weather days, multiplied accordingly for traffic growth, converted to dollar savings using ADOC and PVT values, ramped-in to include all CRCT functions, and then extrapolated for future years.

2.5.3 Recommendations for Measuring CRCT Benefits

The approach taken by CAASD to ascertain or estimate benefits due to CRCT is reasonable. A more meaningful and statistically significant set of benefits would result from the analysis of actual operational data. It is important to have viable performance metrics for the CRCT program. To this end, we would like to recommend the following:

- Collect and analyze operational data.
- Track the usage rate of each CRCT functionality (FCAs, Re-routing, NAS monitor).
- Track instances when CRCT is used (i.e., planning GDP/GS, assessing sector loading/volume, determining congestion at arrival/departure fixes, evaluating proposed Miles-In-Trail (MIT) restrictions.
- Measure the frequency of Traffic Management Initiatives (pre-CRCT versus post-CRCT).
- Collect the severity and scope of MIT initiatives (pre-CRCT versus post-CRCT).
- Compute the percentage of flights impacted by reroutes (pre-CRCT versus post-CRCT).
- Tabulate the frequency of inter-facility coordination (based on CRCT information).
- Monitor the compliance frequency to initial flight plans (due to use of CRCT information).
- Document interdependencies with other decision-support tools for effective planning.
- Gather anecdotal information about benefits of CRCT functionality.

2.6 Anecdotal Information

ASD-400 visited the following facilities and organizations to support this assessment:

- ARTCCs: ZME, ZMP, and ZID. Discussions were held with controllers, AAF, and other AT personnel and supervisors.
- Airlines: NWA, Continental Airlines, and Federal Express. Discussions were held to review current and future NAS initiatives, including the FFP tools. We also talked to dispatchers, the route manager and other AOC management and staff.
- Other: MITRE/CAASD, ATCSCC, AOZ-30 Metrics group and the AOZ-700 CDM program manager for discussions on the CDM-CRCT tool.

Listed below is feedback conveyed to ASD-400 on the various tools:

URET

- From the dispatcher's perspective at two carriers, tracking changes in amendments is not always a good indicator when measuring the performance/benefits of URET.
- From the ATCSCC perspective, when controllers give pilots short direct routes, there could be negative system impacts. Their perspective is system-wide that URET may cause substantial downstream impacts, e.g., aircraft arriving too early.
- NWA recommends that controllers coordinate with the pilots or controller whenever a direct routing over 100 nmi is requested – that is currently not happening consistently. This means frequently optimized flights planned by the dispatchers in the best interest of the company, were overridden by controllers who gave directs to save distance. Continental input was consistent with NWA.
- Replacing paper strips with electronic flight strips can save approximately $120,000 of annual maintenance costs at ZME. This may happen once the backup system is in place.
- Another possible benefit that URET can claim is during in-flight medical emergencies, it might be able to probe the flight and give a direct route, which would save valuable time. NWA indicated they have about 1.5 per day or about .1 percent of their flights; Continental provided a similar rate.
- In ZME, most of the eastbound amendments can be attributed to URET. Similarly, a few RNAV routes over the Columbus, Ohio area lifted restrictions, which resulted in cost savings for Continental.
- Many flight restrictions have been on the books for years. Some will be and have been removed without URET and others are not currently used, due to changes in traffic flows. Since the NRP has been implemented, many inactive restrictions have been removed.
- For arrivals into Nashville International Airport (BNA), originally, the restriction was to descend aircraft to 210 into the low sector. Now, it is possible to wait until the aircraft requests a lower altitude (based on company preference).
- ZME gives directs to non-RNAV-equipped aircraft with vectors and then monitors the traffic. This is more workload intensive for the controller than giving a direct to an equipped airplane.

- If an aircraft is remaining within the sector, the direct amendment is generally not entered into the HOST. URET will re-conform the aircraft's trajectory once it passes the next location in the flight plan.
- ZID had a critical power failure on October 31, 2002. Everything went out, except for URET. This allowed the controllers time to transition to flight strips because URET kept using the last data it had received.
- URET allows the D-side controller to spend more time with the radar and makes R-side trainees better.
- The number of operational errors at ZID has not changed constant even though there has been an increase in traffic. Some controllers feel that URET has contributed to this success.
- URET does not allow the specification of MIT restrictions.
- When the controller is very busy, they may not interact with URET as much.
- Continental Airlines suggested that there should be an Operations Plan or Ops Concept to accompany new technologies such as URET.
- There are not fewer conflict alerts with URET. Conflict alerts are generated by the HOST, which does not have the same flight modeling capability as URET.
- Generally, controllers at both ZID and ZME are extremely satisfied with URET. The controllers at ZME indicated they were very comfortable with the Core Capability Limited Deployment (CCLD) version though they were experiencing significantly more problems than with the prototype.

TMA

- Controllers at ZMP feel that TMA-SC, with time-based metering, has helped their operations and see it as a positive benefit.
- NWA feels that a T1 link from the TMA in ZMP to the Strategic Planning Team (SPT) can reap additional benefits. This capability will assist the SPT in planning the next flight legs better.
- TMA needs to go forward as originally planned. This tool gives the controllers a better comfort level. There will be more benefits if a link can be made available for the airlines (per NWA) at their operations Centers.
- TMA needs to become a certified system so the different performance attributes can be reported into NASPAS. Currently, there is no logging of maintenance actions; delays through OPSNET are not being reported.
- Time-based metering has not been accepted at other FFP1 sites except at ZFW and ZDV, and partially at ZLA.
- The Arrival Sequencing Program (ASP), which was used before TMA, was sufficient as a metering tool; the controllers who used both at ZMP feel TMA is better.
- Adjacent Center feeds would be useful at ZMP, e.g., Chicago. This feed can give more accurate arrival times since a lot of flights coming in could benefit from metering in adjacent Center airspace.
- When TMA fails, the Center resorts to MIT restrictions. When the Host is out of service, TMA cannot be supported by DARC and must resort to MIT operations.

CRCT

- Many users have extolled the capability and flexibility of designing FCAs. No such capability was previously available, thus, re-routing around congested airspace was done in an ad hoc manner and based on conjectures about the fixes that were impacted. The goal is to have full FCA capabilities available by spring 2003.
- The CDM group established in 2000 was a tremendous success. CRCT's future, heading into what-if/sensitivity analysis, is questionable, as CRCT does not provide CDM. The CRCT Core Team will be terminated and become part of CDM. NWA dispatch does not understand where the "collaborative" comes from. At this time, very few airlines are involved in the testing and it is a big disappointment. For CRCT to be a viable tool, the ETMS needs enhancements, data quality must improve, and the Host needs to be upgraded to provide sufficient quality.
- At this time, the level of collaboration between the airlines and the FAA needs to be increased. CDM-Ground Delay Program-Enhanced (GDP-E), which is considered a very successful program, had much greater airline participation during the development phase. In addition, a lack of participation by ATP, AAF, airlines, and other organizations have impeded the process. Sufficient participation by all parties is critical to the success of the effort.

Other

- Generally, the airlines are very upbeat about the potential of CPDLC. Testing needs to continue to show potential benefits.
- PRM, which has been commissioned at MSP since the late 90's, has not being used.

2.7 Summary and Conclusions

The analysis results from this independent assessment suggest that collectively the tools show potential to improve the overall flight operations performance through the NAS. We feel that from a *top-level perspective* the distance savings of .52 nmi per flight/Center[10] from URET and .8-.85 nmi per flight from CRCT[11] that are currently being advertised by the program office is a reasonable portrayal and falls within the pool of available flight efficiency benefits. We feel, each of the three tools that will be deployed during FFP2 have variables and parameters that are at risk of being overstated. Until there is additional solid evidence (through the data) of improved flight times and/or fuel usage, there remains a substantial risk of successfully attaining near-term and long-term benefits for each of the three tools.

One example is the TMA-SC, a tool that is planned to be deployed at four sites in FFP2. While the TMA-SC framework for collecting and evaluating metrics that can support benefits is reasonable, it is difficult to support the benefit projections being carried forward in the IAR and APB until there is some indication that delays (both airborne and departure) and airborne times during the peak arrival times are stabilizing or being reduced at the FFP1 sites. Also, stronger evidence needs to be established that the increased acceptance rates during peak arrival times are

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[10] An examination of one day of ETMS FZ data reveals that for an average flight, about 2.5 Centers are traversed.

[11] AOZ is reporting CRCT savings, in terms of time, of .097 minutes per flight in non-severe weather. This can be translated to approximately .8-.85 nmi saved per impacted flight assuming cruising speed of approximately 420 knots.

active regularly at the evaluated airports. If this is true, then the net effect of slightly longer airborne times and delays, offset by the slight increases in the number of aircraft and passengers utilizing the airport at the carriers preferred time, may be considered a true benefit.

If it is accepted that as a direct result of URET usage, there are additional increased lateral amendments providing distance savings, then URET is certainly making positive contributions at ZID and ZME. It is obvious from our site visits that the controller workforce feels that URET is an excellent tool. At this time, however, it is difficult for ASD-400 to validate, with a high level of confidence, whether or not URET benefits are being measured accurately, and how they will accrue at the other sites. Thus, it is difficult to project benefits based on the *current metrics* (changes in amendments and restrictions) from a relatively small amount of benefits (relative to costs) accumulating at the ZID and ZME Centers; sites that have been in field evaluation for several years. Furthermore, ASD-400 feels strongly that *distance is not the best measure when* measuring the impact of lateral amendments - timesavings and fuel burn savings should be the core measures. This perspective is consistent with the suggested primary OEP macro-level and enroute metrics that are identified in the Preliminary OEP Metrics Plan (Pre-Coordination Draft). The methodology of estimating lifting restrictions and CAASD's application of the Analysis of Restriction Tool (ART) and calculating fuel savings is very reasonable. Yet, there is a high risk of meeting the projected restriction removal levels within a three-year timeframe from IDU at each site. In addition, other Centers have different airspace attributes, e.g., what is the feasibility of URET being used in dense airspace such as ZNY or low demand Centers such as Seattle Center (ZSE), etc. With that said, it remains difficult for ASD-400 to confidently support the benefit claims *by site* at the remaining FFP2 URET sites that are scheduled for deployment over the next few years.

CDM-CRCT is still being tested and has a long way to go since measurable benefits have not been developed and applied during operational use. While CDM-CRCT appears to be a very promising and useful tool in both severe and non-severe weather conditions, it is still very difficult for ASD-400 to objectively support the benefits claims based on the methodology due to rerouting and miles-in-trail management when pre-CRCT baselines have not been well defined. In addition, there needs to be a higher/lower bound for en route impedance, i.e., unavoidable delay within a constrained NAS needs to be factored into the logic. Yet, we recognize the difficulty of developing a benefits baseline at this point in the program and feel that the effort is certainly moving in the right direction. The CDM program office (AUA-700) and their CAASD support, as well as the airlines have been extremely cooperative in helping the ASD-400 assessment team understand the capabilities of the CRCT tool.

Table 2-44 summarizes AOZ's conversion of each of the tool's core metrics projected benefits into projected dollar savings. In some cases, direct conversions from capability to dollars were made, e.g., URET restrictions avoided. In other cases, indirect conversions were made, e.g., URET lateral amendments and TMA throughput. Further study needs to be done to ensure that the metrics that have been identified as giving the FFP2 Program added capabilities are being properly converted into dollar savings.

Table 2-44: Overview of Metric to Dollar Conversion by Tool

Tool	Primary Metric	Primary Capability(s)	Conversion to Dollars	Benefits Projections Supported by Actual Observations	Proportion of Most Likely Life Cycle Benefits (ADOC)
URET	Lateral Amendments	Reduced distance	***Indirect Conversion*** distance savings to delay savings to ADOC savings	Partially, based on performance at two FFP1 sites	59.5%
	Restrictions Avoided	Less fuel usage	***Direct Conversion*** reduced fuel savings to portion of ADOC savings	Partially, based on assumptions of the number of restrictions that can be lifted at FFP1 sites	2%
TMA-SC	Throughput	Additional operations during peak arrival periods	***Indirect Conversion*** observed throughput improvement to reduced delay assumptions to ADOC savings	No, projected delay reductions at four FFP2 sites not consistent with actual delays at MSP FFP1 site since usage began	21.5%
CDM-CRCT	Non-Severe: Unimpeded Distance Savings	Delay savings en route impedance (more efficient routing)	***Indirect Conversion*** distance savings to time savings to ADOC savings	No, analytical exercise, performance tracking planned in Phase 2 per IAR	11%
	Severe: Ground and En route Delay and Disruptions	Cancellations and diversions	***Direct Conversion*** for cancellations and diversions	No, analytical exercise, performance tracking planned in Phase 2 per IAR	6%

Virtually all of the previously requested information has recently been made available to ASD-400 at the time of the assessment. Yet, several deliverables committed to ASD-400 in the Investment Analysis Plan (signed in July 2001) were not provided in a timely manner by the FFP2 program office. One item we did not get access to was the FFP1 Operational Report Card, a survey sent by AOZ to all the AOCs and to members of the Airline Pilots Association (ALPA). Several of the observations in the report card reflect feedback from personnel at those facilities on how the Free Flight tools have affected Air Traffic services. A summarization of the results from the survey would serve as a valuable and credible input to our assessment by reinforcing some of the perspectives of the various AOCs and ALPA stakeholders.[12]

[12] Per AOZ, the responses were not tabulated due to a very low response rate. This survey instrument appears to be a very good vehicle for measuring performance from stakeholders as the program progresses.

In summary, over the recent years, AOZ has done an outstanding job identifying and evaluating selected metrics through the semi-annual Metrics reports, CAASD and NEXTOR documents, etc. No other program office that ASD-400 has worked with on an Investment Analysis in the past six years has put forth such an effort in this very challenging area when measuring the performance of their investment. With that said, until there is convincing evidence that the flight performance at deployed FFP1 sites is improving or not getting worse, some of the metrics being applied to each program/tool cannot be converted directly into *quantifiable, supportable monetized benefits* as illustrated in Table 2-44. Some of the other metrics, i.e., airborne time and fuel savings for TMA-SC and URET, previously identified in various AOZ documents such as the Integrated Program Management Plan that were not addressed in this IA should be addressed for future tracking of the program as well as supporting the OEP metrics initiatives.

Therefore, at this time, with inconclusive evidence of the benefits of the URET and TMA-SC FFP1 programs, it is difficult to fully support the projected benefits of the FFP2 program, i.e., are there achievable properly monetized benefits that can justify the costs? As the FFP1 and FFP2 programs are implemented at the planned sites, it is critical that FAA's senior management promote checks and balances via post-implementation evaluations outside the program office (a Program and Evaluation concept) when assessing a program's benefits. Lastly, we recommend that the FAA undertake a policy review and conduct comprehensive research into appropriate dollar conversion methods for the program's metric that are either demonstrating or projecting improved performance. This also needs to be developed in support of the FAA's portfolio management and value-added approach to investment decisions.

3.0 ASD-400 IAR REVIEW

ASD-400 conducted a review of the draft IAR and the Benefits section of Attachment B, BOE for Cost and Benefits, which was submitted by AOZ. On March 25, 2002, ASD-400/SETA held the initial meeting with AOZ, their support contractors (CAASD and CNA) to discuss the draft FFP2 IAR and BOE submitted by the AOZ. Subsequent meetings resolved several of the discrepancies. By and large, the IAR and BOE documents are comprehensive and well written. Yet, while the majority of the questions/concerns were resolved adequately at the numerous ASD/AOZ benefits meetings in April and May 2002, some of the key issues and concerns were not completely resolved and are noted accordingly.

ASD-400 supports (in no particular order) the following ground rules and assumptions that were made in the BOE section of the IAR. URET, TMA-SC, and CDM-CRCT were addressed. These are by no means all inclusive; but they do represent key drivers in the analysis.

- Fuel cost
- Application of different aircraft for measuring fuel burn rates
- Passenger Value of Time (PVT) values
- Weighting of ADOC values by airport
- Air Traffic Forecasts (TAF at airports, and ARTCC traffic forecasts)
- Downward adjustment in number of passengers because of the influx of regional jets (RJs)
- Passenger load factors, passenger growth rates
- Factors related to fleet mix and influx of RJs
- Average jet ADOC reduction of 1 percent per year due to RJs
- Carrier and commuter passenger capacity growth
- Cancellation and diversion cost factors applied to CRCT
- Use of “Other Airline Costs” category to account for reduction in cancellations and diversions
- Methodology of comparison of “bad day” to average month to account for the cancellations and diversions
- CRCT efficacy factor (per subject matter experts) of total benefits pool
- CRCT ramp-up period to six years to full benefits from FY02
- Computation of interval estimates using Monte Carlo techniques
- Majority of risk ranges including ADOC volatility, traffic projection accuracy
- Adjustment of a scaling factor from ASQP flights

The primary *general assumptions* in the IAR and BOE documents from the AOZ analysis were as follows:

- The life cycle of the program is for the evaluation period through 2015.
- The tools are individually evaluated. Adjustments are not made to account for other large-scale scheduled acquisition per the CIP, NAS Architecture, and those annotated in the OEP.
- The FFP2 benefits in the IAR, which are solely user benefits, are assessed on a site-by-site basis.
- The benefits are additive. There is no attempt to look at the overlap, e.g., more efficient metering to a fix through TMA and an aircraft flying a more efficient route with CRCT.

Listed below are ASD-400's IETs comments on AOZs draft IAR and BOE document. Multiple versions were provided to the IET beginning in late March. The majority of the IETs comments were resolved by AOZ and ASD-400; these cases the final action is annotated **RESOLVED**. If the items were not resolved, the ASD-400 final action has a **Not RESOLVED** annotated. Numbers 1-4 refer to both URET and CRCT concerns; 5-8 refers to URET concerns, and 9-16 refers to CRCT concerns. The TMA-SC BOEs, which was submitted to ASD-400 in mid-April when the program was re-defined is not formally addressed by AOZ. At the time of completion of this document, ASD-400 has not seen revisions to the final TMA benefit estimates. Several comments addressing TMA's performance are provided after the CRCT comments. A summary of these comments is presented in the IE document.

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URET and CRCT

1) IAR (Attachment B) – A 757 aircraft was applied as the representative aircraft for measuring ADOC costs for restrictions lifted.

ASD-400 Comment: A review of four days in 2001 of aircraft that flew through at least one high altitude sector in ZID and ZME shows a completely different story. The dominant aircraft are the MD80s, CRJs, and 737s. More common aircraft in the same two-engine narrow body jet category as the 757 include the A320, B737s, DC9s, and MD80s burn 10-25 percent less fuel than the 757. Using fuel burn flows for representative aircraft that go through five Centers, the average fuel savings per flights should be decremented somewhere between 10 and 15 percent.

ASD-400 Recommendation: CAASD needs to evaluate the aircraft that fly through the NAS and determine if there are significant differences in the fuel flow at the different altitudes times and the fuel flow per minute of a 757 and the other aircraft. The source of the fuel burn data needs to be noted. The fuel burn factor needs to be adjusted to a more reasonable number.

Final Action: **RESOLVED** - CAASD made the adjustments for each Center. The revisions lowered the fuel savings.

2) IAR – How the ADOC was applied to all flights.

ASD-400 Comments:

Comment 1: For a percentage of the flights, credit should only be given to fuel burn savings and a partial maintenance savings since many flights are on time and fly at a slower, more efficient speed to meet their carrier's schedule. About 65-70 percent of the flights fly within their scheduled block time. This means, in most cases, the aircraft are not waiting for gates and not complying with their filed-ETEs. No additional crew and maintenance costs are being accrued when an aircraft meets its block time or is 1 minute early instead of 2 minutes, 2 minutes instead of 3 minutes, etc.

Comment 2: Dollar savings for the base year are the product of the number of affected flights, the ADOC element(s), and PVT (based on average number of passengers and load factor) per incidence. It is hard to determine how the cost per incident is being multiplied by the number of flights involved in the incident. To get the savings for the entire (base) year, the costs of all incidents should be added.

ASD-400 Recommendation: After discussing this internally with the ASD-400 Chief Scientist, Dave Chin, the IET accepts AOZ's position for now. At this time including all three elements in the cost savings is acceptable since there is no clear FAA policy. Currently, ASD-400 and APO are working on standard Benefit Guidelines that will provide guidance and go into AMS for all investment analyses. However, per Dave, due to the uncertainty of how these variables are measured when the airlines are measuring their cost of delay by the airlines, the minimum probability in the triangular distribution needs to be adjusted downward to a lower probability in the investment analysis. This is potentially the biggest swing variable in the entire FFP2 analysis.

Final Action: **RESOLVED –** the IE recommends a research effort to help establish consistent agency policy since this will impact other IAs claiming user benefits.

3) IAR (Attachment B) – There is no mention of the current state of the system with several NRP routes going through the ARTCCs, as well as RNAV routes being established.

ASD-400 Comments:

Comment 1: It appears in the analysis that no adjustments were made for ongoing nationwide RNAV route establishment (at this time, there is an FAA advanced rulemaking activity). These routes are being established in several regions such as Western-Pacific, Western, New England, and Southern. In addition, a recent look at the POET tool revealed 1800-1900 NRP flights in a typical day went through the NAS, with over 100 flights going through ZME and about 200 flights going through ZID daily. It is not clear how these NRP routes that have been in the NAS for several years were decremented from the baseline.

ASD-400 Recommendation: In the IAR it needs to be discussed that there is a current level of user-preferred routing, much of which is independent of URET implementation that has existed before URET was implemented.

Comment 2: These initiatives could be more significant in other Centers. URET is an enabling/enhancing technology. For example, with the density of the New York airspace and the dominance of shorter flights, there are some real differences between Centers such as ZOB and ZID. Without other technologies (e.g., GPS, FMS, etc.) the aircraft have no *ability to* fly "where they want to." Additionally, the document does not mention any "sharing" of benefits with other programs (even their own CRCT).

ASD-400 Recommendation: Discuss the overlapping benefits of re-routing and the additional lateral amendments. It is not clear if there is an overlap per flight in the .097-minute savings (which translates to about a .8-.85 distance savings for CRCT and .52 distance savings for URET, i.e., the competing factors need to be noted).

Final Action: **RESOLVED** – The recommendations are addressed in the BOE document. There is still a overlap with CRCT not being addressed in the URET writeup.

4) IAR – The Free Flight benefits streams table needs more detail.

ASD-400 Comment: This is hard to support until more detail is made available. Detailed spreadsheets, due from AOZ on March 1, 2002, were not received by ASD-400 until March 25.

ASD-400 Recommendation: Break out benefit streams by PVT and ADOC for each of the categories where benefits are being gernerated, i.e., lateral amendments, restrictions lifted, non-severe weather, and severe weather.

Final Action: **RESOLVED** – the benefits by tool were broken out in the BOE Tables B-5, B-9, and B-18 in the final BOE document.

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URET

5) IAR (Attachment B) – Per Table B-3, how the extrapolation of avoided restrictions to other sites is being done.

ASD-400 Comments:

Comment 1: At this time, 20 avoided restrictions through ZID (out of 403 restrictions or about 5 percent) have been identified (with little details) in the monthly FFP1 URET Daily Measures reports and the bi-annual FFP1 performance metrics reports. The IET accepts what has been shown but still need to see the specifics like the type of aircraft, fuel saved per flight at the higher altitude and the number of days impacted. We need more explanation on how Table B-2 (FFP2 BOE) was generated. An explanation that has the following type of information as illustrated below would be useful.

Restriction Lifted or Modified	Type of Aircraft	# of Flights Impacted Per Day (Non-Severe Weather??)	Estimated Fuel Savings (per day)	Estimated Fuel Savings (per year)	Savings Per Restriction ($)

However, we have not seen similar data through ZME except hearing that five restrictions have been lifted. When the extrapolation is done on Table B-3, several FFP2 sites show more restrictions than ZID, e.g., ZJX – 67 out of 281 restrictions, ZBW-49 out of 106 restrictions, ZNY-49 out of 118 restrictions, etc. We need to understand the extrapolation better based on what the current restrictions are and the ones that will be eliminated solely because of URET.

Comment 2: The latest information we have seen (per CAASD briefing slide given October 31, 2001) is that there are about 1,500 current restrictions at the FFP2 sites or 115 per Center; there is an average of 330 per FFP1 Center. A low estimate that we have seen for ZID was 112 restrictions lifted because of URET; with 20 restrictions attributed to URET that have been lifted in two years. On the surface, it seems that 112 is an ambitious number. Furthermore, it is impossible to support a full ramp-up of 18 months from the PCA date based on the rate of restriction removal at ZID and ZME.

Comment 3: We need more explanation of the ART model. It appears that results in Tables B-3 and B-4 are based on assumptions in the model. Are the inputs into the model a set of all routes that are candidates for restriction removal? One good day of ETMS data is used and the results are extrapolated for a year's worth of traffic (good and bad weather). Are the static altitude restrictions impacted by weather problems? If so, shouldn't the removal of static altitudes be evaluated for different weather scenarios?

Comment 4: It takes considerable time to get LOAs and MOUs agreed to by the regions. How many are currently approved? or in the works? because of URET implementation? intra-facility restrictions? Both?

ASD-400 Recommendation: The IET finds the estimates plausible, however, until we get more information on actual restrictions that have been lifted (both intra and inter-center) or are candidates to be lifted at the FFP1 airports we find this element to have a high risk.

Final Action: **RESOLVED** - ASD-400 analysts sat down with CAASD and AOZ to get a better understanding of the components of the ART model and how it was applied. The comments were addressed, e.g., the ramp up time was changed from 18 months to 36 months. This is still considered a high-risk claim.

6) IAR (Attachment B) – The mileage savings (distance) on a per flight basis is very difficult to translate timesavings into a lower ADOC. Several of the flights are wind-optimized flights that will fly considerably longer distances but will save fuel.

ASD-400 Comments:

Comment 1: The AOZ/CAASD analysts assume that direct routes and shorter distances are always the best option. This ignores the fact that jet routes and wind-optimized routes are not necessarily the shortest distances. Furthermore, shorter distances do not guarantee less fuel. Airlines adherence to the schedule (time predictability and on-time performance) is their most important objective (what is best for the airline), at times even more important than more efficient fuel consumption. The analysis needs to consider time saved and fuel burn saved instead of distance saved. The URET analysis implies that amendments are positive in contradiction of CRCT's goal to reduce the number of amendments, even on non-severe weather days. An airline we spoke with considers amendments to be constraints and would prefer to have fewer of them.

Comment 2: Distance is not a good measure of "savings." Wind-optimized routes are typically longer than direct routes, but often provide the most significant savings. Flight time is a "more" relevant measure of efficiency. Are there any measurements of flight timesavings due to URET? Currently, the IAR simply converts distance to time via the aircraft speed into dollars, which is not correct.

Comment 3: The data should be more detailed. There is no reason to apply to all flights. We assume the results are based on actual flights, and therefore the data should be able to be provided in "bins" as illustrated below.

No. of Flights	Distance Saved (nmi)	Time Saved (min)
X	1-10	
Y	11-25	
Z	26-50	
……	>50	

ASD-400 Recommendation: Provide supporting details to the IET on a typical day savings such as the average of 5,000 nmi at ZID. A list of all flights or binning the flights (as in the above table) that traverse ZID or ZME and have lateral amendments would support the distance savings claims a lot better. ASD-400 and CAASD need a session to go through the CRCT trajectory model, which is generating the results.

Final Action: **RESOLVED** - CAASD showed the IET distributions from different days. The IET still stands by its comments that distance saved is not the best measure of performance and will give a deceptive portrayal of the dollars saved through the life cycle of the program.

7) IAR (Attachment B) – The daily savings of 5000+ nmi through ZID and 3000+ nmi through ZME from lateral amendments with URET might be justified. This is translated to 1.22 nmi per aircraft which implies that 5000+/1.22 daily flights at ZID interact with URET and 3000+/1.22 daily flights are impacted at ZME because of URET operability.

ASD-400 Comment: The claim is made that the URET facilities save more/lateral amendments. How many are made due to user requests? Are more requests denied in the non-URET Centers? Do the Centers "volunteer" more amendments? Are miles saved numbers based on 10 busiest hours at ZID and 8 busiest hours at ZME with NO SCALING to account for the other traffic?

ASD-400 Recommendation: Same as #6. Need clearer interpretation on how to read Figure B-2. ASD-400 needs to see supporting data to support the figure of an average day for both URET Centers and non-URET Centers (.70 nmi savings).

Final Action: **RESOLVED** - Supporting data provided by CAASD for multiple days at ZID.

8) IAR (Attachment B) – The application of the factor of .52 nmi saved per flight for lateral amendments in a Center with URET deployed.

ASD-400 Comments:

Comment 1: The average .52 nmi saving is based on the 10 busiest hours of the two busiest days of the week. It appears that this .52 nmi savings is applied to all flights at any time. Furthermore, other technological and procedural changes through more efficient traffic flow management as well as capacity changes at the airports might have contributed to this change in distance traveled.

Comment 2: Regression analysis is performed using total distance savings at Centers as the dependent variable and the corresponding number of flights at the Centers as the independent variables. Next, the slope is calculated to estimate the average saving per flight. We do not understand this regression because we are ultimately interested in total savings at the Center. So, if we have the total savings (the dependent variable), why use a regression to get the average savings? Is it because the regression was based on four days of data and the CRCT trajectory model estimates total savings? Still, we do not see the point of using a regression analysis. We need more explanation. Furthermore, if regression is an essential part of the analysis then regression diagnostics, including R^2 and other details such as residual plots should be provided.

Comment 3: It states .62 nmi/flight for jets (80-90 percent) and .52 nmi/flight for turboprops, how do you get to .52 nmi/flight overall? Shouldn't it be a .60-.61 nmi/flight savings when you weight it? – *This was cleared up by AOZ.*

Comment 4: ASD-400 needs to see a breakdown of the actual flights where there were savings due to lateral amendments through URET before supporting the per flight savings. A list of flights needs to be made available which has average distance for the flight without a lateral amendment and an average distance for the flight with the lateral amendment.

Comment 5: As part of ASD-400's independent evaluation, we are currently looking at the trends in airborne times and filed-ETEs for several of the primary city pairs that go through ZID and ZME as well as other Centers in the NAS. A first-cut look at average filed-ETEs of 40 randomly selected city pairs that fly through ZME and ZID show that the filed-ETEs are increasing very slightly of a four-year period of 1998 through 2001, (about 1-2 percent longer ETEs) with ten of the city pairs improving and the other 30 getting worse.

ASD-400 Recommendation: Depends on what our validation and AOZ supporting data indicate. Currently, the IET is taking an independent look using POET and ASQP, CODAS and ASPM data to look at the change in airborne times of flights that go the high and super-high sectors in ZID and ZME. The findings will be included in the independent assessment. Also, CAASD and AOZ needs to look at comments #2, #3, #4, and #5 and provide clearer explanations to make these paragraphs read better.

Final Action: Mostly **RESOLVED, the ASD-400 validation supports the distance savings (see Section 2.3)** - In the BOE, the portrayal of the pool of benefits saving 400 million nmi excess distance is overstated. This needs to be qualified better since in reality, optimized flights

are a combination of wind-optimized (more efficient fuel/less distance savings) and direct routes (more efficient fuel/less distance savings.
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CRCT

9) IAR (Attachment B) – There is no mention of the planned initiatives of the ETMS that will enable the CRCT functionality. For example, the MIT and re-routing "what if" capabilities need to be explained better such as the testing at ZKC that has revealed significant potential for relaxing these MITs, or removing some altogether.

ASD-400 Comments:

Comment 1: Some MITs are unnecessary and too stringent. Any tool that can be used to determine the times when certain MITs are needed would be an asset. Is there a documented case of where CRCT was used to evaluate different MITs at ZKC with a resulting benefit, e.g., during an unscheduled equipment outage or inclement weather? A detailed description of any actual benefits due to relaxed/eliminated MITs needs to be given. How have certain lifted MITs contributed to the benefits?

Comment 2: The IAR needs to note the ETMS enhancements (versions 7.4, 7.5, etc.) will enable much of these initiatives to happen. There is some risk to the schedule for implementing the additional capabilities to make CRCT successful.

ASD-400 Recommendation: Discuss what the current reference system looks like, number of MITs per day, number of MIT spacing restrictions that can possibly be avoided, etc.
The executability and implementation of the future versions of ETMS needs to be noted as a risk in the Risk Section. At this time, this concern appears not to be a key driver with the benefit calculation since full benefits are not coming in until 2007.

Final Action: **RESOLVED** – There is a discussion on MIT spacing restrictions in the BOE document. Work with Centers to establish causality of MIT restrictions and frequency of relaxing or lifting them similar to how restructure static altitude restrictions.

10) IAR (Attachment B) – It is noted that 1,926 flights out of 33,974 are impacted on the severe weather days.

ASD-400 Comment: This needs to be explained with more detail. What do the 33,974 flights represent? Shouldn't there be more like 50,000-60,000 daily flights or are you assuming many of these flights are cancelled, thus, giving the 33,000+ number. The .10*.097 minutes saved factor needs to be applied against a subset of the total flights in the NAS. The 10 days per year appears reasonable, but what is the criterion for bad weather? All day convective weather in the majority of the CONUS?

ASD-400 Recommendation: The IET needs to have clearer descriptions in the document so the reader can follow the basis for establishing the estimate.

Final Action: **Partially RESOLVED -** CAASD and AOZ still have not clarified how all 1,926 flights on all 10 days will be eliminated because of better CRDSS. Are some of the inefficiencies in these flights inevitable as well as unavoidable?

11) IAR (Attachment B) – The statement of "flight impedance" in the NAS.

ASD-400 Comments:

Comment 1: Several thousand daily flights that file IFR flight plans have the same origin and destination in NAS. If one includes these flights, then zero distance will not mean zero time even in the most optimal situations. I am assuming that you have excluded these flights in your calculations. Is distance the actual distance traveled or the great circle distance? How is "delayed" defined when separating delayed flights in the terminal area from undelayed ones? Is the "impedance" caused by reduction in the speed due to MIT? Are the deltas in a minimum filed-ETE versus actual airborne time? How are adjustments made for wind optimized trajectories or jet streams when longer distances may actually result in shorter times? Direct trajectories are not always optimal for fuel or time.

Comment 2: The idea behind CRCT is coordination between airlines and Centers to better file flight plans. As stated in this section, this will reduce changes to flight plans after take-off which can save fuel and reduce communication between pilots and Centers. This makes sense, however, it contradicts with the message that URET sending more amendments is better.

Comment 3: On the surface, the 10 percent proportion of the total benefits pie from CRCT appears reasonable; however, to base it on a .97 minute factor is not correct because the NAS is a constrained system and there will always be inefficiencies; i.e., it is impossible to make minimum unimpeded times when there are multiple competing factors that impact the dynamics of the system, i.e., the gap should never be completely down to zero. The .97 minutes of en route impedance needs better supporting BOE.

ASD-400 Recommendation: **Not RESOLVED, but it is okay**. This is simply a difference in of opinion in applying methodologies between different organizations. The IET feels that if the impeded time is established, then a part of that time will not get down to zero, since there always will be constraints with some flights in the NAS.

12) IAR (Attachment B) – No baseline reference system ("status quo") for CRCT has been described.

ASD-400 Comment: It is difficult for comparison purposes to understand why the current way of re-routing aircraft is so much more inefficient than with CRCT implemented. An explanation of the current problem that CRCT is trying to resolve is needed in the IAR.

ASD-400 Recommendation: See comment in #13 below.

Final Action: **RESOLVED** - This has been addressed through the sampling of 25 of the 1,926 cases, which reveals an average of 42nmi distance savings from the reference system.

13) IAR (Summary of 1998 MITRE/CAASD Study) – To calculate the improvement possible with CRDSS, the authors hand-crafted some improved flight plans that might have been filed without en route deviations. For a sub-sample of these cases, they computed an average savings of 42 nmi.

ASD-400 Comment: The idea behind calculating possible improvements is feasible. The determination of what constitutes an "improved flight plan" and evidence that the improved flight plan is better would determine the type of benefits possible.

ASD-400 Recommendation: There needs to be a simple illustration like the table below of some of the specific flights that were rerouted from the bad weather day that gave 42 nmi savings (that were handcrafted).

City Pair	Filed Flt. Distance	Actual without CRCT – based on ZKC or ATSCC testing	Actual with CRCT	Filed with CRCT	Flight Savings
A-B					
D-C					

Final Action: **Not RESOLVED, but okay**. CAASD was not able to recreate any of this at this point in the program (it was stated in the BOE document). It is something that needs to be done as the program is being measured over time.

14) IAR (Attachment B) – The expected operational impacts from these CRCT functions in "severe weather" are decreased flight times and distances, a reduction in departure delay, and a reduction in the number of flight cancellations and diversions.

ASD-400 Comment: Most of the impacts appear reasonable except decreased flight times and distances. Though CRCT will provide "what if" tools to evaluate the best re-routing plan, the reroute chosen may be one in which the flight time and distance has increased to ensure safety. Not sure if decreased flight times and distances are a benefit in lieu of safety.
.
ASD-400 Recommendation: There needs to be some discussion on Safety - about how with this tool, there is still compliance to sector loadings, separation criteria, lack of operational errors, and so forth.

Final Action: **Partially RESOLVED** - The estimated benefits of each of the categories is conservative but is not complete since safety implications are not addressed. Future work can address, a reduction in the "propagation of delay" (downstream impacts) as an area that CRCT may be able to improve considerably more than advertised.

15) IAR (Attachment B) – During severe weather, traffic flow management can use CRCT functions to reroute traffic.

ASD-400 Comment: From the studies of the CRCT tool, it seems that CRCT will enable traffic flow managements to run "what-if" scenarios to evaluate different re-routing strategies, not implement them. How would determining the best reroute provide benefits? Is actual implementation of reroute issues addressed? Does CRCT functionality actually help with implementation? The benefit should be measured after the implementation of a reroute determined by CRCT.

ASD-400 Recommendation: Mention next steps that are planned to capture the performance better. Is there some kind of formal measurement process being established - like what has been done with URET?

Final Action: **Not RESOLVED** – The IET did not see any indication of a formal measurement strategy that has been established or executed at any of the prototype sites.

16) IAR (Attachment B) – An adjustment to these counts was necessary since ASQP data only included the top 10 or so air carriers (about 35 percent of the total flights). A multiplier was used to account for the other flights.

ASD-400 Comment: We agree that ASQP only includes the top 10-12 carriers so an adjustment needs to be made if all carriers are considered.

ASD-400 Recommendation: A few sentences on how the multiplier derived would be useful.

Final Action: **RESOLVED** - Appears from the text in Section 3.3.2.2.1 of the BOE was made.

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TMA-SC

ASD-400 met with AOZ in late-April and May 2002 to discuss the development and presentation of the TMA benefits in the IAR. AOZ concurred that part of the benefits estimates need to be adjusted. AOZ's position was to review and adjust the MEM outputs; this will give moderately lower projections. ASD-400 feels that the projected delays are overstated, primarily the departure delays at all four airports. We agreed because of a lack of time for the June 12, 2002, JRC, AOZ would not make any numerical changes of the projected benefits to the IAR and JRC briefing package. Also, at this time, there is significant risk of attaining the benefits, given our perspective of how the benefits should be measured.

ASD-400's primary concerns are: 1) the frequency and rate of the build up of the departure delays, especially at MEM, 2) the estimates that the delays will be reduced when MSP, which has been PCA for a significant amount of time, is not showing any reduction or mitigation in flight timesavings or ground delays, 3) the conversion of better acceptance rates during peak arrivals to dollar savings when the evidence (from the first year beyond PCA) is not apparent at MSP, 4) not spreading demand to other hours when the demand begins to approach or exceed the capacity[13], and 5) the need to present the benefits on an airport-by-airport basis with higher-granularity modeling (e.g., SIMMOD). With a 1-year period between the JRC 2a and JRC 2b decision, more robust modeling could have been performed. AOZ felt this was might be a reasonable way of modeling TMA assuming there is sufficient funding allocated.

[13] This is based on our experience from working with ACB-330 using NASPAC and CAASD using the Detailed Policy Assessment Tool (DPAT) for several high-visibility efforts. Both of these models spread demand via the Frataring Algorithm mentioned previously.

ASD-400 Comments:

Comment 1: It is difficult to understand how departure delays are building up in the modeling during peak arrival times with or without TMA. About 67 percent of the projected delay timesavings are on the ground at the four airports during the peak arrival pushes. In 2010, there are over 15,000 hours of annual departure delay savings at the four airports once TMA goes time-based metering. With an average of roughly 850 departures at CVG, 700 at MEM, 850 at STL, and 875 at IAH projected by 2010, this translates to about 30 hours a day (1,800 minutes per day) or .75 minutes (45 seconds) saved per departure with TMA versus without TMA -- the denominator is **all departures** on about 330 days of the year when in reality there will only be a significantly smaller subset of departures impacted. This translates into over a 2-minute savings per affected flight if 1/3rd of the daily departures are affected. This appears highly unlikely with the new runways coming into three of the airports from 2005-2007. Furthermore, this implies that the demand-to-capacity ratio will be consistent with what we are currently observing.

The IET took a quick look at MSP pre-PCA and post-PCA with OOOI data. It revealed that during four peak arrival times since PCA in 2001, the taxi-times increased by .30 minutes from the same months in 2000; over eight months the times increased in six of the months. Whenever modeling is performed, there needs to be a feedback loop with the ***simulated results.*** *For example, a check needs to be made* ***when time based metering is effective*** *(the first year 11,600 hours are estimated to be saved on the ground at these airports)* ***with the actual operational data*** *at MSP where time-based metering is being conducted.*

The taxi-out times at MSP have increased since 1996 from a 50th percentile of 14 minutes to 16 minutes in 2000 to 16.5 minutes in 2001. Shouldn't we expect them to decrease or at least remain the same per the modeling results for the FFP2 sites? The number of Ops from January through August of 2000 and 2001 is identical, about 1,430 per day.

Excerpts from the semi-annual AOZ Performance Metrics reports indicate the following findings from the ground times:

1) ***June 2001 Report:*** *The taxi-out results shown here are similar to those reported in the December 2000 report (Reference 3). The taxi-in results shown here reflect a smaller increase than reported in the December report. Notably, at that time, the median taxi times were unchanged, indicating that some extremes in the data were responsible for the increased taxi times. Increases to taxi times could also be the result of increased operations rates.*

2) ***June 2001 Report:*** *Multiple regression models were developed to estimate the potential effects of TMA on taxi times at DEN. These models were developed using the same explanatory variables as the models for operations rates. The results of the models show that TMA appears to have the small but statistically significant effect of increasing taxi-out time by 0.34 minutes and increasing taxi-in time by 0.22 minutes.*

3) ***December 2000 Report:*** *At MSP taxi out and taxi in times have increased by .55 and .29 minutes based on three months of data.*

Comment 2: It appears the deterministic queuing model is only building ground queues when taxiing out. If that is the case, there are inconsistencies with what really happened at MSP noted in Comment 1 above. A quick look at the data showed small reductions in the gate delays during peak times at MSP with TMA but taxi-in times are increasing, i.e., both gate delay and taxi delay savings need to be captured. The time change in each ground element needs to be reported by AOZ.

Comment 3: We need to understand the impact of slight increases in demand relative to capacity from the reference case. A quick look of filed-ETEs and airborne differences using ASPM shows very few differences (less than 1 percent of the time) the deltas are over 45 minutes. It is important if we can understand the model's behavior better, i.e., what are the queue durations and a distribution of the number of aircraft experiencing queues. It appears at MEM that very large queues are building up to lengths that would never happen and would be unacceptable to the carriers; therefore, causing a change in the schedule. Is there a trace file of the deltas that can give a frequency distribution of the delay durations to justify the results?

Comment 4: It is true that the airlines aim to get as many operations in as possible during their "peaks?" Yet, the demand may be redistributed, i.e., the flight performance during the other hours may have gotten better or worse. The performance during these "non-peak" times need to be understood when the # of operations during "peak" times are increasing. Also, it is still not clear from the BOE if the increased operations rate at ZLA is based on a half-hour or a one-hour time period.

ASD-400 Recommendation: AOZ needs to review the simulation results and adjust the delays, especially the departure delays. In the future, higher-granularity modeling needs to be applied in lieu of the simplistic deterministic framework that was applied to project the benefits. Evaluation of the operational data as part of post-implementation assessments need to continue with allowances made for the short-term impacts in the traffic levels after September 11, 2001.

Final Action: **NOT Resolved** - ASD-400 did not see the updated benefit projections. We feel the benefit projections that are in the IAR, APB that were presented to the JRC are overstated and adjustments should be made in the future.

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Overall Limitations: After several review sessions with AOZ, ASD-400 still sees limitations in the following areas. Several previously listed limitations (over 20) were dropped from the list and resolved by AOZ in April and May. Comments represent general statements to improve the analysis. In many cases, additional detailed documentation in the BOEs, with supporting clarifications and adjustments, is needed.

- The 400 million nmi benefits pool claimed in the BOE Overview Section 3.1 is extremely hard to support. The assumption of 30,000 flights per day saving 35 nmi or greater is overstated. Other ASD-400 analyses have shown up to a maximum of 12 nmi per day for a smaller number of flights from departure fix to arrival fix. An analysis in Section 3.3.2 shows a difference of 4.5 nmi measuring all but 200 nmi from both the origin and destination airports.
- Four "good" weather ETMS days of data seems insufficient for determining the global benefits. Only looking at good weather days will not provide the statistical impacts. What percentage of time are the "good" weather days? Were these "good" in Centers only, or NAS-wide? It is recommended that bad weather days be considered whenever extrapolating to the NAS.

- There is very limited discussion about the interactions between TMA, URET, CRCT, and other non-FFP2 supporting tools such as WARP. For example, almost $300M has been spent on WARP, which is a critical piece of information for the controllers to make URET effective. A good place to start is ZTL where both TMA and URET are deployed. Future work needs to show synergies between each tool and how a given flight that interracted with the tools received a flight amendment through URET or was metered in through TMA was impacted, etc.

Final Comments: At this time, while there are some differences of opinions, ASD-400 supports the benefits analysis that AOZ has conducted for the IA. Overall, there is a MEDIUM level of risk in attaining the projected benefits. Relative to other FAA program offices, the FFPO has provided a very high level of commitment of measuring the performance of their tools. AOZ's support contractors, which included CAASD and CNA, were very accommodating and supportive from late-March to the end-of-May as we were conducting this independent assessment. Nevertheless, as we have repeatedly noted throughout this assessment, we feel multiple top-level performance indicators (whether they are positive or negative) need to be recognized and reported, consistent with what has been presented for each tool's metrics in the FFP2 Integrated Program Management Plan (Chapter 6) and the OEP Metrics Plan to accurately portray the performance (in terms of flight efficiency and delays) of the program.

APPENDIX A

OPTIMAL TRAJECTORY GENERATOR (OPGEN) MODEL

Appendix A: OPGEN Model

The OPGEN is a trajectory model that provides the capability to generate optimized (direct/wind) flight trajectories based on the aircraft type and performance (fuel flow and weight), scheduled arrival times, desired time en route, SUA, prevailing winds and other weather situations, delays and other ATC restrictions, but subject to meeting the overall flight schedule. OPGEN also compares each flight's projected trajectory with other flight profiles and readjust trajectories to resolve conflicts. Various thresholds may be input into the model, which allow delays to increase up to the threshold chosen.

OPGEN computes an optimized flight trajectory, which minimizes the en route fuel burn subject to meeting the desired time en route. In certain cases, due to the violation of constraints such as SUAs, the optimized trajectory will minimize the time en route.

OPGEN uses a SUA Activity file, which contains the Find Crossings information on when and where aircraft enter and exit a given sector. Traffic and trajectory files must be generated through a preprocessor using ETMS data. In this analysis, in order to qualify as a potential optimized (direct/wind) flight, specific cutoff flight level, e.g., FL240 and minimum flight length, e.g., 500 nmi must be specified. Flights that are at or above the cutoff flight level and at or above the minimum flight length receive full optimization. However, those flights that are below the cutoff flight level and above the minimum flight length receive partial optimization. Another input required for an OPGEN run is the Band file, which contains the permissible flight levels by direction. The last input file is the Wind file with the winds aloft data used by the optimization process to reduce fuel burn.

The aircraft types depicted Table A-1 had sufficient fuel and performance to support OPGEN's data input requirements to fly optimized (direct/wind) routes.

Table A-1: Aircraft Types

OPGEN Aircraft Type	ETMS Aircraft Type
A300	332, A300, A306, A30B, A330, A3ST
A310	A310
A320	A20, A319, A32, A320, A321, A340, A340-600
B727-200	727, B72, B720, B721, B722, B727, B727-200
B737S	736, 737, 737B, B73, B731, B732, B733, B734, B735, B736, B737, B738, B73A, B73B, B73C, B73F, B73S
B747-200	A124, B747, B747-200, B74A, B74R, B74S
B747F	B74, B741, B742, B743, B744, B74B, B74F
B757-200	757, B752, B753, B757, B757-200
B767-200	767, B762, B763, B767, B767-200
DC10-30	DC10, DC10-30
DC8-63	B701, B703, B707, IL62, KC10
DC9-50	DC9, DC9-50
L1011	L101
MD11	MD11
MD88	MD80, MD82, MD83, MD87, MD88, MD90

APPENDIX B

NATIONAL AIRSPACE PERFORMANCE ANALYSIS CAPABILITY (NASPAC) MODEL

Appendix B: NASPAC Model

This overview provides additional details and insights into the NASPAC Simulation Modeling System (SMS) that provided the results for the system delay metric, annotated as ***operational delay*** in this report in Section 2.4.4.1.

NASPAC is a discrete-event simulation model that tracks aircraft as they progress through the NAS and compete for ATC resources. Resources in the model include airports, sectors, flow control restrictions, and arrival and departure fixes. NASPAC evaluates system performance based on the demand placed on resources modeled in the NAS and records statistics at 80 of the nation's busiest airports. NASPAC simulates system-wide performance and provides a quantitative basis for decision making related to system improvements and management. The model supports strategic planning by identifying air traffic flow congestion problems and examining solutions.

NASPAC analyzes the interactions between many components of the ATC system and the system's reaction to projected demand and operational changes given airport and airspace capacities. The model was designed to study nationwide system performance rather than localized airport changes in detail. Airports are modeled at an aggregate level. An aircraft's itinerary may consist of many flight legs that an aircraft will traverse during the course of a day. If an aircraft is late on any of its flight legs, then successive flight legs may be affected. This is the way the model captures the rippling effect of passenger delay.

NASPAC records two different types of delay: passenger and operational. Passenger delay is the difference between the scheduled arrival time in the Official Airline Guide (OAG). Passenger delay is *not reported* in this analysis. Operational delay is the amount of time that an aircraft spends waiting to use an ATC system resource. Resources, whether they are in the departure phase, cruise phase or arrival phase include: airports, arrival and departure fixes, flow control restrictions, and sectors. Note: Airborne and ground delay are reported in the analysis. Since NASPAC builds flight itineraries from the OAG and the DOT's ASQP, one of the strengths of the model is providing a quantitative assessment of how delay at one airport will affect the delay at subsequent airports defined in the flight itinerary.

In this analysis, the flight profiles are developed through NASPAC's trajectory builder and future demand generator. The trajectory builder algorithm develops flight profiles from positional information (latitude, longitude, altitude, and time) contained in the ETMS. Each navaid (waypoint) recorded at five-minute (or less) intervals, serves as position information for each flight from which a route is developed. Intermediate positions are interpolated as a result of a flight in transition (climbing or descending). A great circle (direct point-to-point) trajectory is constructed for flights that are missing from the ETMS data.

The FDG is used to develop flight itineraries for the future years. The program references the TAF to determine growth rates at over 400 of the nation's largest airports. Flights for the 80 NASPAC airports are increased over the current number of departures and arrivals based on the growth rates from the TAF. The departure and arrival times of these additional flights are centered near the most desirable times for passengers, without exceeding the acceptance rate of the airport. When the maximum capacity of the airport has been exceeded for that hour, the new flights are moved one hour before or after the exceeded time. Flights are then aligned together to form a flight itinerary that describes the day's activity. These itineraries are based on aircraft type and minimum turnaround times for that airport.

APPENDIX C

TOTAL TRAFFIC TOOL (T^3)

Appendix C: Total Traffic Tool

The Total Traffic Tool (T^3) has been developed for the FAA and NASA. T^3 is used to capture aircraft proximity events. A proximity event is when two aircraft violate a user-specified separation. Proximity events are also referred to as conflicts, or more accurately, potential conflicts. T^3 identifies additional events between pairs of aircraft based on user-specified separation criteria: horizontal and vertical. T^3 also identifies proximate aircraft within a user-specified distance from the conflict pair, i.e., a "conflict cluster." Proximity event occurrence rates and characteristics such as conflict geometry and relative closing velocity are used to compare the relative complexity of different demand scenarios.

For this analysis, T^3 was run on the optimized 2001 and 2005 scenarios to characterize the number and types of conflicts that controllers would need to resolve with en route aircraft flying optimized trajectories.

Table C-1 shows the number of hours by sector that had eight or more conflicts during a modeled 2001 day.

Table C-1: Sectors and Number of Hours

Sector	Number of hours with > 8 conflicts/hour
ZAB90	1
ZAB93	4
ZAU25	2
ZAU34	1
ZAU46	1
ZAU76	1
ZAU82	4
ZBW38	2
ZBW46	1
ZDV08	1
ZDV28	1
ZDV37	1
ZFW42	1
ZID80	2
ZID82	4
ZID83	2
ZID85	7
ZID86	1
ZID87	8
ZID88	8
ZID89	3
ZID98	1
ZJX47	1
ZJX68	1

Table C-1: Sectors and Number of Hours (Cont'd)

Sector	Number of hours with > 8 conflicts/hour
ZKC26	1
ZKC84	1
ZLA26	1
ZLA27	3
ZLA37	3
ZLA38	5
ZLA39	6
ZLA40	2
ZMA02	2
ZME25	1
ZME26	1
ZMP38	1
ZNY75	4
ZOA32	1
ZOA34	6
ZOB27	2
ZOB36	1
ZOB46	3
ZOB48	7
ZOB57	4
ZOB66	7
ZOB67	4
ZOB77	1
ZTL32	1
ZTL39	1

The areas of increased conflicts shown above coincide with the areas of increased traffic as described in Section 2.2.3. The resolution of these conflicts will require aircraft to be maneuvered off of their desired trajectory to maintain safety. The impact of these resolution maneuvers has not been investigated. For the future scenario, it is assumed that a growth in the number of conflicts will occur at a rate similar to the overall growth in traffic.

The above table demonstrates that by allowing aircraft to fly their preferred route with SUA avoidance as the only constraint outside of the terminal environment, the demands on the air traffic controller also increase. With an increase in the number of required conflict resolution maneuvers, the demand for additional support tools, such as URET, will also be necessary.

APPENDIX D

ETMS VISUALIZATION TOOL

Appendix D: ETMS Visualization Tool

EVT was used in the FFP2 evaluation in two ways. One is that EVT provides an interface with ETMS data and the program OPGEN. EVT in this mode produces flight trajectories based on a combination of ETMS time data (TZ), arrival (AZ), Flight Plans (FZ), and departures (DZ). EVT provides filtering for "bad" ETMS data prior to producing the OPGEN needed trajectories. All flights can be output or various criteria (minimum flight length, specified equipment types) can be specified to restrict the flights. Secondly, EVT provides a mechanism for extracting all flights that cross specific regions (e.g., Memphis Center - ZME) as specified by the boundary latitude/longitude coordinates. In this mode it provided the specific airport pairs (departure-arrival) for further analysis and comparison with flights that didn't cross the Centers.

The ETMS FZ file is used to get the arrival and departing airports and the scheduled arrival and departure times, for each flight. These flights are mapped to the AZ and DZ files where the scheduled times are replaced by the actual times, if located. The result is then mapped to the TZ file to obtain the trajectory between the airports. Once all the flight data has been processed, each flight is tested to determine whether it crosses the sector boundary. If it does, the approximate entry and exit times will be calculated based on the velocity of the plane at the previous TZ point. In addition, the great circle distance inside the region will be calculated along with the total flight distance between the departing and arrival airports (unless a cutoff distance from the airports is specified, in which case the distance will exclude the beginning and end of the flight).

Once the city pairs were output for all the flights that intersected the ZID or ZME Centers, the data was examined and city pairs for flights that were in the Centers for 300 seconds or less were removed before comparing 2001 and 1998 data. When creating the input files for OPGEN, only flights for which all the relevant data were located (airports, intermediate points, times) and which had the desired equipment type (RNAV capable) were included.